THE

BOOK OF NATURE.

BY

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PREFACE.

THE present volumes, which are designed to take a systematic, but popular, survey of the most interesting features of the general SCIENCE OF NATURE, for the purpose of elucidating what has been found obscure, controverting and correcting what has been felt erroneous, and developing, by new and original views and hypotheses, much of what yet remains to be more satisfactorily explained, derive their origin from the following circumstances:

Towards the close of the year 1810 the author had the honour of receiving a visit from a deputation of the Directors of the SURREY INSTITUTION, founded on what had been antecedently the LEVERIAN MUSEUM, with a request on the part of their Chairman, Dr. Adam Clark, that he would undertake a department of lectures in that literary and scientific establishment; the generous offer of leaving to himself ination of time, terms, and subject. his inability of acceding to at that particular period;

little more at liberty not long afterwards, he readily consented, on a second application by Dr. Lettsom and other Directors; and the ensuing volumes contain the course of study he ventured to make choice of; the lectures having been divided into series, and delivered in successive years.

It was his intention to have carried the plan to a somewhat more protracted extent, though the present is sufficiently complete for the outline laid down: but, though earnestly and repeatedly pressed to proceed further, or even to go over the same lectures again, an augmented sphere of professional duties compelled him, with much reluctance, to decline the invitation; and the same cause has prevented him, till the present period, from fulfilling a subsequent request to submit them to the public; though he has always intended to do so as soon as he could find leisure.

As the lectures were delivered from general recollection, though with the author's manuscript at hand, it is possible that those who took notes may find a few passages in the present text slightly varied from what was uttered at the time.

he believes that, upon an accurate examina-
h discrepancies will be found but few,

own reward. Its proprietary shares, like those of every other literary institution in this metropolis, were soon found to have been fixed at too low a price. And, a difficulty having been experienced in obtaining the consent of every proprietor to an adequate additional subscription, it was wisely resolved, almost from the first, to make a yearly encroachment upon the capital, and to maintain the Institution at its zenith of vigour and activity till the whole of such capital should be expended, rather than to let it live through a feeble and inefficient existence, though for a longer period of time, by limiting it to the narrow scale of its annual income alone.

To the crowded and persevering audience by which, from year to year, the author had the gratification of being surrounded, many of whom are yet within the circle of his acquaintance and friendship, he still looks back with gratitude; and can never forget the ardour and punctuality of their attendance. It is a lively recollection, indeed, of the manner in which his labours were received, when delivered, that chiefly induces him to hope for a favourable reception of them in their present form.

The progress of time, and the mental activity with which it has been followed up, have strikingly confirmed various hints and opinions which he ventured to suggest as he proceeded, and

have introduced a few novelties into one or two branches of science since the period referred to; but the interval which has hereby occurred has enabled the author to keep pace with the general march of the day, and to pay due attention to such doctrines or discoveries in their respective positions of time and place.

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THE

BOOK OF NATURE.

SERIES I.

LECTURE I.

ON MATTER, AND A MATERIAL WORLD.

In the comprehensive range of science proposed to be treated of in the Surrey Institution, the department to which I shall have the honour of beseeching your attention will be that of natural philosophy, or physics, in the most extensive sense of these terms: that branch of science which makes use of the individual principles and discoveries of every other branch within the range of nature, as the architect makes use of the bricks, the mortar, the wood, and the marble of different artizans, and builds up the whole into a perfect edifice; which takes a bird's eye view, as it were, of a picturesque and spreading landscape from some commanding eminence; and, without having laboured in the details of arranging the ground, of cultivating the soil, of planting the woods, of winding the rivers, of enriching the scenery with flocks, herds, bridges, and buildings, points out the general connexion

of part with part, and the harmony which flows from their combined effect. This, indeed, is to employ these terms in a somewhat wider sense than has been assigned to them in modern times; for even the Natural Philosophy of Lord Bacon, though it embraces the two divisions of special physic and metaphysic, as he calls them, does not extend to the doctrine of "the nature and state of man," which is transferred to another division of general science*; yet that the study of physics, or natural philosophy, had this more extended meaning among the Greeks and Romans, is clear, since the poem of Empedocles on "Nature," and that of Lucretius, on "the Nature of Things," the two most complete physiological works of which we have any account in antiquity, were expressly formed upon this comprehensive scale; and hence the philosophy of geology and mineralogy, the philosophy of botany and zoology, the philosophy of human understanding, the philosophy of society and whatever relates to it, or general and synthetical surveys of these different departments of science, are as equally branches of physics, or the nature of things, as equally part of the BOOK OF NATURE, as any separate branch which is more ordinarily so arranged.

* Advancement of Learning, b. ii. p. 52. 56. vol. i. 4to. General science is here divided into three classes: I. Doctrina de numine, or Divine Philosophy. II. Doctrina de naturâ, or Natural Philosophy. III. Doctrina de homine, or Human Philosophy. The common stem from which they ramify is denominated philosophia prima, primitive, summary, or universal philosophy.

Thus explained, the scope of the study before us is almost universal, and only a small portion of it can be engaged in during a single series. I shall endeavour to advance in it as I am able; and the infinite variety it presents to us will at all times, I trust, prevent the pursuit from proving dull or uninteresting. Could it indeed be completed as it ought, it would constitute the PHILOSOPHIA PRIMA, or universal science of the great author I have just adverted to.

My sole object, however, is to communicate information so far as I may be able; to exhaust nothing, but to touch upon many things; to give a desire for learning, rather than to consummate the learning that may be desirable; to run over the vast volume of nature, not in its separate pages, but in its table of contents, so that we may hereafter be the better prepared for studying it more minutely, and for feeling in some measure at home upon the various subjects it presents to us.

Yet, after all, lectures alone can do but little, whatever the energy or perspicuity with which they may be delivered. They may, perhaps, awaken a latent propensity, or enkindle a transient inclination; but unless the new-born flame be fed and fostered, unless it be nourished by study, as well as excited by hearing, it will perish as soon as lighted up; or, if it continue, will only blaze forth in a foppery of knowledge far more contemptible than the grossest ignorance.

Let us then enter upon our respective duties with equal ardour. The path of science is open

to every variety of age, and almost to every variety of education. Thousands at this moment behind are pressing forward, and will surpass those that are before; and the richest and most gratifying reward I can ever receive will be, to find that many to whom this course of study is delivered will hereafter be able to communicate to me the same proportion of information, which it is my duty to suppose I can at present communicate to them.

One of the first enquiries that can ever press upon the mind must relate to the nature of MATTER, and the origin of the world around us: what is this common substance from which every thing visible has proceeded, and to which every thing visible is reducible? has it existed from all eternity? or has it been called into being by the voice of an Omnipotent Creator? and in either case, has it uniformly exhibited its present harmony and arrangement, or has there been a period in which it was destitute of form and order, a waste and shapeless chaos?

These are questions which have tried the wisdom of man in all ages; and, I may add, which in all ages have proved its littleness, and the need we stand in of illumination from a superior source. Such, upon one or two points, we have received; upon the rest we are still ignorant; and, but for what we have received, we should have been still ignorant upon the whole.

If we search into the systems of all the ancient schools of philosophy, amidst an infinite variety of jarring opinions in other respects, we find them,

perhaps without an exception, concurring in a belief of the eternity of matter, or that general substance which constitutes the visible world around us; which was sometimes conceived to be intelligent in many of its corpuscles, and unintelligent in the rest, as was taught by Democritus; sometimes intelligent as a whole, though unintelligent in its separate parts, as taught both by Aristotle and Plato; and sometimes unintelligent in all its parts and particles, whether united or disjoined, which formed the dogma of Epicurus. Under some modification or other, however, the doctrine of the eternity of matter appears to have been universal among the philosophers of ancient nations. That a loose and floating idea of its creation by the energy of a pure intelligence is occasionally to be met with, and which probably existed as a remnant of patriarchal tradition, must be admitted; for the Tuscans were generally allowed to have entertained such an idea, and we find it frequently adverted to and opposed by the leaders of the different schools, but in no instance does it seem to have been embodied or promulgated as a doctrine of philosophy.

The grand motive for this general belief appears to have been a supposed absurdity in conceiving that any thing could be created out of nothing.* The Epicureans, and many other

* This, and two or three subsequent passages in the present lecture, are given summarily from an ampler and more recondite view of the subject in the author's prolegomena to his translation of "THE NATURE OF THINGS."

schools of philosophers, who borrowed it from them, perpetually appeal to this position. It was current, however, among many of the philosophers of Greece at a much earlier period; for Democritus expressly asserted, according to Diogenes Laertius, "that nothing could spring from nothing, or could ever return to nothing." Epicurus, in the few fragments of his that have reached us, echoed the tenet in the following terms: "Know first of all, that nothing can spring from non-entity." It was thus given by Aristotle: "To suppose what has been created has been created from nothing, is to divest it of all power, for it is a dogma of those who pretend thus to think, that every thing must still possess its own nature."* From the Greeks it passed to the Romans, and appears as follows in Lucretius:—

> ubi viderimus nihil posse creari
> De nihilo, tum, quod sequimur, jam rectius inde
> Perspiciemus.*
>
> Admit this truth, that nought from nothing springs,
> And all is clear.

And it was thus long afterwards reiterated by Persius, as the common doctrine of his day:—

> gigni
> De nihilo nil, in nihilum nil posse reverti.†
>
> Nought springs from nought, and can to nought return.

The Greeks themselves, however, seem to have received it from the East, and to have become acquainted with it as a branch of gym-

* De Rer. Nat. i. 157. † Sat. iii. 83.

nosophy; for it constitutes, even in the present day, a distinct doctrine of Brahminical religion, and is thus urged in univocal terms in the Yajur Veid, in the course of an address to Brahm, or the Supreme Being: "The ignorant assert that the universe, in the beginning, did not exist in its author, and that it was created out of nothing. O ye, whose hearts are pure! *how could something arise out of nothing?*" *

This reasoning seems, indeed, to have spread almost universally, and perhaps from the same quarter; for we find many of the Jewish theologians, and not a few of the Christian fathers, too much influenced by Platonic principles, giving countenance to the same doctrine, though probably not to the full extent of the Platonic school. Thus the author of the Book of Wisdom, a book written in Greek instead of in Hebrew, and hereby proving his own æra as well as the school in which he had studied, expressly asserts that "*The almighty hand* of the Lord created the world out of *unfashioned* (amorphous) *matter,*" ἐξ ἀμόρφου ὕλης †; while Athenagoras, Tatian, Theophilus of Antioch, Athanasius, and Gregory Nazianzen appear to have concurred in the same opinion; and Justin Martyr affirms it to have been the general creed of his own æra: "For that the word of God," says he, "*formed the world out of unfashioned*

* The passage is quoted from M. Anquetil De Perron's Latin version. The reader may find various similar extracts in Sir William Jones's works, vol. vi. 4to. edit.

† Cap. xi. 17.

matter, Moses distinctly asserts, Plato and his adherents maintain, and ourselves have been taught to believe."

This is one specimen of the very common attempt in the writings of the fathers to blend the narrative and doctrines of Moses with the principles of Platonism, which, in truth, had been embraced by many of them before their conversion. The text of Moses, when accurately examined, will be found, if I mistake not, to lead us to a very different conclusion. This text consists of the first and second verses of the book of Genesis, and is as follows: "In the beginning God created the heaven and the earth; and the earth was without form and void, and darkness was upon the face of the deep (or abyss); and the Spirit of God moved upon the face of the waters." Now in this passage we seem to have a statement of three distinct facts, each following the other in a regular series: first, an absolute creation of the heaven and the earth, which, we are expressly told, took place foremost, or in the beginning; next, the condition of the earth when it was thus primarily created, being amorphous and waste, or, in the words before us, "without form and void;" and, thirdly, the earliest creative effort to reduce it from this shapeless and void or waste condition into a state of order and productiveness — "the Spirit of God moved upon the face of the waters." And hence, to maintain from the Mosaic narration that the heaven or the earth existed in a waste and amorphous mass ante-

cedently to the first act of creation, is to derange the series of such narration, and to put that process first which Moses has put second.

I enter not here into the correctness of the general rendering, nor into the exact import of the word ברא, "created;" for whatever be the rendering, the same consecutive order of events must be adhered to, and the same conclusion must follow. I am perfectly ready, however, to admit that ברא does by no means at all times import an absolute creation out of nothing, but, like *create* in our own language, that it occasionally denotes the formation of one thing out of another; yet when we are told that, if Moses had really intended to express an absolute creation of the earth out of nothing, he would have used some other word, which should have limited us to this idea, I confidently put it to any critic, what word he could have employed specially appropriated to such a purpose, and limited to such a sense, at the time he wrote? or even what word, thus restrained, he could select in our own day, from any spoken language throughout the world? Words are not invented for an exclusive expression of solitary facts, but for general use. The creation of the world, or of any thing whatever, out of nothing, is a fact of this kind; and no language ever had or ever will have a term precisely struck out for the purpose of representing such an idea, and exclusively appropriated to it: and assuredly there could be

no such word at the time Moses first spoke of the fact, and communicated the doctrine; as, antecedently to this, it could not have been called for. And it will not be questioned, I think, that there is more sound sense and judgment in employing, as on the present occasion, a well understood term, that comes nearest to the full extent of the idea intended to be conveyed, than to invent a new word for the purpose, that nobody has ever heard of, and, consequently, that nobody can comprehend the meaning of, till the very term that is thus objected to, or some other word from the vulgar dialect, shall be had recourse to as its interpreter. Yet although, in the Hebrew Scriptures, the word ברא is occasionally used synonymously with our own terms, "to make, produce, or cause to be," to import a formation from a substance already in existence, we have sufficient proof that it was also understood of old to import emphatically, like our own word "create," an absolute formation out of nothing. Maimonides expressly tells us, that it was thus understood in the passage before us, as well as in all others that have a reference to it, by the ancient Hebrews; while Origen affirms, that such was its import among many of the Christian fathers, whatever might be the opinion of the rest, and forcibly objects to the passage just quoted from the Book of Wisdom, as a book not admitted into the established canon of Scripture.

Still, however, the doctrine of a creation of

something out of nothing was generally held to be a palpable absurdity; and a variety of hypotheses were invented to avoid it, of which the three following appear to have been the chief; each of them, however, if I mistake not, plunging us into an absurdity ten times deeper and more inextricable. The first is that of an absolute and independent eternity of matter, to which I have already referred; the second, that of its emanation from the essence of the Creator; the third, that of idealism, or the non-existence of a material world.

I have already remarked, that the FIRST of these was modified under the plastic hands of different philosophers of antiquity into a great variety of shapes; and hence, in some form or other, is to be traced through most of the Grecian schools, whether of the Ionic or Italic sect—or, in other words, whether derived from Thales or from Pythagoras. In no shape, however, is it for a moment capable of standing the test of sober enquiry. We may regard matter as essentially and eternally intelligent, or as essentially and eternally unintelligent; as essentially intelligent in its several parts, or as essentially intelligent as a whole. The dilemma is equal in all these cases. Matter cannot be intelligent as a whole, without being intelligent in every atom, for a concourse of unintelligent atoms can never produce intelligence; but if it be intelligent in every atom, then are we perpetually meeting with unintelligent compounds resulting from

intelligent elements. If, again, matter be essentially eternal, but at the same time essentially unintelligent, both separately and collectively, then, an intelligent principle being traced in the world, and even in man himself, we are put into possession of two co-eternal independent principles, destitute of all relative connexion and common medium of action.

The SECOND HYPOTHESIS to which I have adverted is not less crowded with difficulties and absurdities; but it has a more imposing appearance, and has hence, in many periods and among many nations, been more popular, and was perpetually leading away a multitude of the philosophers from the preceding system. According to this hypothesis, the universe is an emanation or extension of the essence of the Creator. Now, under this belief, however modified, the Creator himself is rendered material; or, in other words, matter itself, or the visible substance of the world is rendered the Creator; and we merely shift the burden, without getting rid of it. There can be no difficulty in tracing this doctrine to its source. It runs, as I have already observed, through the whole texture of that species of materialism which constitutes the two grand religions of the East—Brahmism and Buddhism; and was undoubtedly conveyed by Pythagoras, and, perhaps, antecedently, by Orpheus (if such an individual ever existed, which Cicero * seems to have disbelieved, from a passage of Aristotle,

* De Nat. Deor. l. i.

not to be found, however, in any of his writings that have descended to us), into different parts of Greece, in consequence of their communications with the gymnosophists. From Pythagoras it descended to Plato and Xenophanes, and, under different modifications, became a tenet of the academic and eleatic schools. I have already quoted the principle on which it is founded, from M. Anquetil du Perron's translation of the Oupnek'-hat, or Abridgement of the Veids *; the passage at large is as follows, and developes the entire doctrine as well as the principle: "The whole universe is the Creator, proceeds from the Creator, exists in him, and returns to him. The ignorant assert that the universe, in the beginning, did not exist in its Author, and that it was created out of nothing. O ye, whose hearts are pure! how could something arise out of nothing? This First Being alone, and without likeness. was the ALL in the beginning: he could multiply himself under different forms; he created fire from his essence, which is light, &c." So, in another passage of the Yagur Veid, "Thou art Brahma! thou art Vishnu! thou art Kodra! thou art Prajapat! thou art Deïonta! thou art air! thou art Andri! thou art the moon! thou art substance! thou art Djam! thou art the earth! thou art the world! O lord of the world, to thee humble adoration! O soul of the world! thou who superintendest the actions of the world! who de

* Tom. i. Paris, 1802.

stroyest the world! who createst the pleasures of the world! O life of the world! the visible and invisible worlds are the sport of thy power! Thou art the sovereign, O universal soul! to thee humble adoration! O thou, of all mysteries, the most mysterious! O thou who art exalted beyond all perception or imagination! thou who hast neither beginning nor end! to thee humble adoration!"*

As this doctrine became embraced by many of the Greek and Roman philosophers, it is not to be wondered at that it captivated still more of their poets; and hence we find it, with perhaps the exception of Empedocles and Lucretius, more or less pervading all of them, from Orpheus to Virgil. It is in reference to this that Aratus opens his Phænomena with that beautiful passage which is so forcibly appealed to by St. Paul in the course of his address to the Athenians on Mar's-hill †, of which I will beg your acceptance of the following version:—

From God we spring, whom man can never trace,
Though seen, heard, tasted, felt in every place;
The loneliest path, by mortal seldom trod,
The crowded city, all is full of God;
Oceans and lakes, for God is all in all,
And we are all his offspring.‡

* See Transl. of Lucr. i. p. 282. † Acts, xvii. 28.

‡ Ἐκ Διὸς ἀρχώμεσθα, τὸν οὐδέποτ' ἄνδρες ἐῶμεν
Ἄῤῥητον· μεσταὶ δὲ Διὸς πᾶσαι μὲν ἀγυιαὶ,
Πᾶσαι δ' ἀνθρώπων ἀγοραί· μεστὴ δὲ θάλασσα,
Καὶ λιμένες· πάντη δὲ Διὸς κεχρήμεθα πάντες·
Τοῦ γὰρ καὶ γένος ἐσμέν. Lib. i. 1.

to

So Æschylus, in a passage still stronger in point, and imbued with the full spirit of Brahmism:—

> Jupiter is the air;
> Jupiter is the earth;
> Jupiter is the heaven;
> All is Jupiter.*

But perhaps the passage most express is one contained in a very ancient Greek poem entitled De Mundo, and ascribed to Orpheus, in the original highly beautiful, and of which, for want of a better, I must trouble you with the following translation:—

> Jove first exists, whose thunders roll above;
> Jove last, Jove midmost, all proceeds from Jove.
> Female is Jove, immortal Jove is male;
> Jove the broad earth — the heaven's irradiate pale.
> Jove is the boundless spirit, Jove the fire
> That warms the world with feeling and desire.
> The sea is Jove, the sun, the lunar ball;
> Jove king supreme, the sovereign source of all.
> All power is his; to him all glory give,
> For his vast form embraces all that live.†

* Ζεὺς ἔστιν ἄιθὴρ,
Ζεὺς τε γὴ·
Ζεὺς δε ὄυράνος,
Ζεὺς τα πάντα.

† Ζεὺς πρῶτος γενὲτο, Ζεὺς ὕστατος ἄρχικεραυνος
Ζεὺς κεφαλη, Ζεὺς μὲσσα. Διὸς δ' εκ παντα τετῦκται·
Ζεὺς ἄρσην γενέτο, Ζεὺς ἄμϐροτος ἔπλετο νυμφη·
Ζεὺς ποθμὴν γαῖης τα καὶ ὄυρανοῦ ἄστὲροεντος·
Ζεὺς πνοιη παντῶν· Ζεὺς ἄκαματα πυρος ορμὴ·
Ζεὺς ποντοῦ ῥιζα· Ζεὺς ἥλιος ἠδε σεληνη·
Ζεὺς ϐασιλεῦς· Ζεὺς ἄυτος ἄπαντῶν ἀρχιγενεθλος·
Ἓν κρατος ἓις Δαιμὼν γένετο, μεγας ἄρχος ἄπαντῶν·
Παντα γάρ ἓν μεγαλῳ Ζηνος ταδὲ σωματι κειται.

Ex. Apul.

This doctrine has not been confined to ancient times, or to the boundaries of India and the republics of Greece and Rome; it has descended through every age, and has its votaries even in the present day. M. Anquetil du Perron, whom I have already spoken of, as the Latin translator of the Oupnek'-hat, or Upanishad, from the Persian version, has himself distinctly avowed an inclination to it; the writings of M. Neckar are full of it*; and M. Isnard has professedly advanced and supported it in his work, "Sur l'Immortalité de l'Ame," printed at Paris in 1802. I do not know that it exists at present to any great extent in our own country; but if we look back to something less than a century, we shall find it current among the philosophers of various schools, and especially that of which Lord Bolingbroke has been placed at the head; and hence running through every page of the celebrated Essay on Man, in the composition of which it is probable that Mr. Pope was imposed upon by his noble patron, and was not sufficiently alive to the full tendency of its principles. The critics on the Continent, however, perceived the tendency on its first appearance; and hence its author was generally, though incorrectly, denominated the modern Lucretius, and the poem itself was regarded as one of the most dangerous productions that ever issued from the press; as a most insidious attempt, by confining the whole of our views, our reasonings, and our

* See Sir W. Jones's Works, i. p. 448.

expectations to the present state of things, to undermine the great doctrines of a future state and the immortality of the soul. In our own day we allow to it a very liberal extent of bold imagery and poetic licence, and with such allowance it may be perused without mischief; but a few verses alone are sufficient to prove its evil bearing, if strictly and literally interpreted. The following distich, for example, beautiful as it is in itself, discloses the very quintescence of Spinosism * : —

> All are but parts of one stupendous whole,
> Whose body nature is, and God the soul:

and the general result drawn from the entire passage, which is too long to be quoted, is no less so : —

> In spite of pride, in erring reason's spite,
> One truth is clear, WHATEVER IS, IS RIGHT.

If every thing be right at present, there is no necessity for a day of correction or retribution hereafter; and the chief argument afforded by nature in favour of a future existence is swept away in a moment. Unite the propositions contained in these two couplets, and illustrated through the whole poem, and it follows that the universe is God, and God the universe; that amidst all the moral evils of life, the sufferings of virtue, and the triumphs of vice, it is in vain to expect any degree of compensation or adjust-

* See the author's prolegomena to his translation of the Nature of Things, p. cxxvi.

ment in a future state; every thing being but an individual part of one stupendous whole, which could not possibly exist otherwise; and that the only consolation which remains for us under the pressure of pain or calamity is, that if *we* are not at ease, there are others that are so — that if *our* own country is devoured by war, or desolated by pestilence, there are countries remote from us that know nothing of such afflictions — that the *general good* is superior to the *general evil*, and made to flow from it, and, consequently, that *whatever is, is right*:—

> If plagues and earthquakes break not heaven's design,
> Why then a Borgia or a Catiline?

The THIRD HYPOTHESIS to which I have referred, is that of the idealists, or those who maintain that there is no such thing as a material or external world; that the existence of man consists of nothing more than impressions and ideas, or of pure incorporeal spirit, which surveys every thing in the same unsubstantial manner as the visions of a dream. Some of the tenets of Malbranche appear to have a tendency to this theory; but it has been chiefly developed in modern times by Bishop Berkeley and Mr. Hume. Their premises are indeed somewhat different, but their conclusion is the same; excepting that the argument is pressed much farther by the latter than was ever intended by the former, and leads to more dangerous consequences. In Germany, Professor Kant has al-

lowed a part of this tenet, as well as parts of various other tenets *, to enter into his system, or that which he chuses to distinguish by the name of the *Transcendental Philosophy*, and which not long since bade fair to obtain an universal sway over the Continent, though for some years it has appeared to be considerably declining in its reputation. It was my intention to have traced the origin of the ideal hypothesis, and to have pointed out its sophisms, but our time will not allow me; and it is the less necessary, as I shall have an opportunity, on a future occasion, of reverting to all these various conjectures and examining them at full length.†

But why, after all, is it necessary to support the proposition, that "nothing can spring from nothing?" Why may not *something spring from nothing*, when the proposition is applied to Omnipotence? ‡ I may be answered, perhaps, because it is a self-contradiction, an impossibility, an absurdity. This, however, is only to argue in a circle; for why is it a self-contradiction, or an impossibility? "It is impossible," said M. Leibnitz, "for a thing to be and not to be at the same time." This impossibility I admit; because, to assert the contrary, would imply a self-contradiction absolute and universal, founded upon the very nature of things, and consequently ap-

* Degerando, Histoire Comparée des Systemes de Philosophie, tom. ii. 17.

† Vol. III. Series III. Lect. V.

‡ See the author's Prolegomena, et supra, p. lxxviii.

plicable to Omnipotence itself. But the position that "nothing can spring from nothing" is of a very different character: it is necessarily true when applied to man, but it is not necessarily true when applied to God. Instead of being *absolute* and *universal*, it is *relative* and *limited;* the nature of things does not allow us to reason concerning it when its reference is to the latter: and hence we have no authority to say that it is impossible to the Deity; or to maintain that an absolute creation out of nothing by the Deity is an absurdity or self-contradiction. It is absurd to suppose that matter does not exist; it is absurd to suppose that it does exist eternally and independently of the Creator; it is absurd to suppose that it constitutes the Creator himself: but, as it is not absurd to suppose its absolute formation out of nothing by the exercise of an almighty power, and as one of these four propositions must necessarily be true, reason should induce us to embrace the last with the same promptitude with which we reject the other three.

So far, indeed, from intimating any absurdity in the idea that matter may be created out of nothing by the interposition of an almighty intelligence, reason seems, on the contrary, rather to point out to us the possibility of an equal creation out of nothing of ten thousand other substances, of which each may be the medium of life and happiness to infinite orders of beings; while every one may, at the same time, be as distinct from every other, as the whole may be

from matter, or as matter is from what, without knowing any thing farther of, we commonly denominate spirit. Spirit, as generally used among modern metaphysicians, is, to say the most of it, but a negative term employed to express something that is not matter; but there may be ten thousand somethings, and substrates of being, and moral excellence and felicity, which are not matter, none of which, however, we can otherwise characterise. Yet why, between all or any of these and matter itself, there should be such an utter opposition and discrepancy as was contended for by Des Cartes, and has since been maintained by most metaphysicians, I cannot possibly conjecture; nor conceive why it should be universally thought necessary, as it still appears to be thought, that the essence of the eternal Creator himself must indispensably consist of the essence of some one of the orders of beings whom he has created.—Why may it not be as distinct from that of an archangel as from that of a mortal? from the whole of these various substances, which I have just supposed, and which we cannot otherwise contemplate or characterise than by the negative term Spirit, as it is from matter, which is more immediately submitted to our eyes, and constitutes the substrate of our own being and sensations?

Matter, then, we are compelled to regard as a substance created out of nothing by an intelligent first cause; himself immaterial, self existent, eternal, and alone; and of matter the whole

visible universe is composed. It is arranged and regulated by an extensive code of laws, of which, however, we know but a few; and which give birth to a multiplicity of concrete forms, under which alone we are capable of contemplating it: for no effort has hitherto succeeded in ultimately enucleating the compound and tracing it to its elementary particles. We may divide and subdivide as we please; but when we have followed it up into its subtlest rudiments, its most retiring principles, by the aid of the best glasses which the best art of man can provide for us, we learn no more of the real nature of its primitive essence than we do from an acorn or a pebble.

But we are as ignorant of matter in its total scope as we are of it in its elementary particles. We can examine it as it exists in the globe, but the globe on which we tread is but as a drop to the ocean; the earth is surrounded by other planets, by other worlds, by other systems of worlds; all of which, we have reason to believe, are composed of the same substance, and regulated by the same laws. We stretch out our view on every side, but there are still worlds beyond us; we call in the aid of the best glasses, but they still surpass our reach; till at length we resign ourselves to imagination, and in the confusion of our thoughts and the weakness of our language we speak of space as being filled, and of matter as being infinite.

This view of the subject has given rise to a variety of magnificent speculations, at which

I shall just glance, without meaning to dwell upon them. Is all this immensity of matter, this universe of worlds within worlds, and systems within systems, the result of one single fiat of the great Creator? Did the Power that spake it into existence give it from the first the general order and harmony and perfection that prevail at present? or did he merely produce a vast central and aggregate chaos, as the rude basis of future worlds, the parent-stock or storehouse from which they have since issued by a series of distinct efforts and evolutions? or, thirdly, has every separate system of worlds, or every separate planet, been the result of a separate birth, and a separate act of creation?

It is of little importance which of these splendid fancies we adopt; for all of them are but fancies, and built upon conjecture alone. In a course of philosophical enquiry, however, it becomes us to be acquainted with their existence; and to be informed, beyond this, that the second is the speculation which has been more generally espoused by philosophers; that, I mean, which conceives the existence of a central and primary chaos, from which all the heavenly bodies have successively proceeded, of whatever kind or description, whether suns, stars, comets, or planets; though the mode by which such efforts have been produced has been variously accounted for. Des Cartes seems to have supposed stars to have preceded planets in the order of creation; and that the earth was at first a

star, and continued so till rendered opake by having its bright surface encrusted with grosser and untransparent matter, and drawn into the vortex of the solar system; and Leibnitz adopted his conjecture. Whiston conceived it to have been originally a comet, the rude materials of which constituted the chaos of the earth; and Buffon, to have consisted of a comet and a portion of the sun's exterior limb or edge carried off by such comet, in consequence of its having given the sun an oblique stroke in the course of its orbit; the chaos of the earth being thus formed by the vapoury substance of the impinging comet uniting with a portion of the sun's igneous mass; and in this manner he endeavoured to account for the production of every other planet of the solar system.

But of all this class of speculations, (for assuredly they deserve no higher character), the most splendid and comprehensive is that which was first embraced by Dr. Herschel, and was perhaps an improvement on a prior hypothesis of M. Buffon; but which, so precarious is the life of a philosophical hypothesis, he himself discarded, not many years afterwards, for something newer. It supposes the existence of an immense mass of opake but igneous matter, seated in the centre of universal nature; that the sun and every other star were originally portions of this common substance; that it is volcanic in its structure, and subject to eruptions of inconceivable force and violence; that the sun and every other luminary

of every other system were thrown forth from it at different times, by the operation of such projectile powers; and that these, possessing in a great degree the qualities of the parent body, threw forth afterwards at different times, by means of similar volcanoes, portions of their own substance, each of which, by the common laws of projectiles, assumed an orbicular motion, constituted a distinct planet, and became the chaos of a rising world.* Hence, according to this comprehensive and daring hypothesis, the existing universe has acquired its birth; hence new systems of worlds are perpetually rising into being, and new planets are added to systems already created.

But worlds and systems of worlds are not only perpetually creating, they are also perpetually diminishing and disappearing. It is an extraordinary fact, that within the period of the last century, not less than thirteen stars in different constellations, none of them below the sixth magnitude, seem totally to have perished; forty to have changed their magnitude by becoming either much larger or much smaller; and ten new stars to have supplied the place of those that are lost.† Some of these changes may perhaps be accounted for by supposing a proper motion in the solar or sidereal systems, by which the relative positions of several of the

* Phil. Trans. vol. lxxiv.

† See Dr. Herschel's Observations compared with Flamsteed's, Phil. Trans. vol. lxxiii. art. 17.

heavenly bodies have varied. But this explanation, though it may apply to several of the cases, will by no means apply to all of them; in many instances it is unquestionable, that the stars themselves, the supposed habitations of other kinds or orders of intelligent beings, together with the different planets by which it is probable they were surrounded, and to which they may have given light and fructifying seasons, as the sun gives light and fruitfulness to the earth, have utterly vanished, and the spots which they occupied in the heavens have become blanks. What has thus befallen other systems will assuredly befall our own; of the time and the manner we know nothing, but the fact is incontrovertible; it is foretold by revelation, it is inscribed in the heavens, it is felt throughout the earth. Such is the awful and daily text; what then ought to be the comment?

LECTURE II.

ON THE ELEMENTARY AND CONSTITUENT PRINCIPLES OF THINGS.

Our study for the present lecture is the first or simplest principles of bodies, so far as we have hitherto been able to obtain any degree of knowledge upon this recondite enquiry, and the means by which they are combined or separated from each other, so as to produce different kinds and orders of sensible objects.

A very slight contemplation of nature is sufficient to show us that matter under every visible form and modification, when regarded in its general mass, is perpetually changing; alternately living, dying, and reviving; decomposing into elements that elude our pursuit; and recombining into new shapes and energies and modes of existence. The purest and most compact metals become tarnished or converted into a calx or oxyde on its surface, and the most durable and crystallized rocks crumble into granules; and the matter constituting these oxydes and granules, by an additional series of operations, is still farther decomposed, till every vestige of their late character is lost, and the elementary principles

of which they consisted are appropriated to other purposes, and spring to view under other forms and faculties. The same process takes place in the organized world. The germ becomes a seed, the seed a sapling, the sapling a tree; the embryo becomes an infant, the infant a youth, the youth a man: and having thus ascended the scale of maturity, both, in like manner, begin the downward path to decay; and, so far as relates to the visible materials of which they consist, both at length moulder into one common elementary mass, and furnish fresh fuel for fresh generations of animal or vegetable existence; so that all is in motion, all is striving to burst the bonds of its present state; not an atom is idle; and the frugal economy of nature makes one set of materials answer the purpose of many, and moulds it into every diversified figure of being and beauty and happiness.

It has hence been said, that matter is necessarily corruptible, and is perpetually changing from its intrinsic nature, and that the physical and moral evils of life are mainly attributable to this perverse and incorrigible propensity. Such was the doctrine of many of the most eminent schools of ancient philosophy, both of Greece and Asia, and such continues to be the doctrine of various schools of the present day; a doctrine which has not unfrequently been considered as of the utmost importance, and as forming the best defence of the benevolence of the Supreme Architect; who, we are told, not-

withstanding all the pains and calamities, the tumults and disorders of nature, has made the most of matter that it would admit of; and has tempered it not only with a positive predominancy of good over evil, but with as much and as real good as could possibly be infused into it.

To argue thus is to revive the theory of pure Platonism, far too extensively introduced into the Christian world, as I hinted in our last lecture, upon the first conversion of the Grecian philosophers, who had been chiefly students in the Platonic school; and to suppose the existence of matter as an independent and eternal principle. "God," says the sublime but mistaken founder of this school, "wills, *as far as it is possible*, every thing good and nothing evil *:" "but it cannot be that evil should be destroyed, for there must always be a something contrary to good †," a ξύμφυτος ἐπιθυμια, "an innate propensity to disorder ‡," in that eternal and independent principle of matter out of which all visible things are created.

How much more consolatory, as well as agreeable to right reason, is the view taken of this abstruse subject in the pages of genuine, unsophisticated, and unphilosophised revelation, in which the present is represented as a state, not of actual necessity, but of pre-ordained probation; willed, in infinite wisdom, by the great

* Theæt. t. i. p. 176. † Id.

‡ Phileb. See also Brucher, Hist. Phil. lib. ii. cap. viii. § 1

first cause, to promote the best ultimate happiness of man; and matter as a substance produced out of nothing, by his almighty fiat! It was one of the express objects of the preceding lecture to prove, not only that matter does exist, in opposition to those who have thought it expedient to deny the being of a sensible and material world, but that it could not exist by any other means; and that, whilst there is no self-contradiction or absurdity in contending that matter, and that ten thousand other substances than matter, may be produced out of nothing by the energy of an infinite and omnipotent intelligence, there is so pure and perfect an absurdity in endeavouring to account for its existence upon every other theory which has hitherto been invented, that right reason should induce us to embrace the former opinion with the same promptitude with which we fly from every opinion that opposes it.

Matter, then, is the production of an almighty intelligence, and as such is entitled to our reverence; although, from a just abhorrence of many ancient and not a few modern errors, it has too often been regarded in a low and contemptible light. Though not essentially eternal, as was contended for by all the schools of Greece and Asia, nor essentially intelligent, as was contended for by several of them, it evinces in every part and in every operation the impress of a divine origin, and is the only pathway vouch-

safed to our external senses by which we can walk—

Through nature up to nature's God;

that God whom we behold equally in the painted pebble and the painted flower—in the volcano and in the corn-field—in the wild winter-storm and in the soft summer moon-light. Although, when contemplated in its aggregate mass, and especially in its organized form, it is perpetually changing, it is every where perfect in its kind, and even at present bears indubitable proofs of being capacified for incorruptibility. In its elementary principles it is maintained by the best schools of both ancient and modern times to be solid and unchangeable; and, even in many of its compound forms, it discovers an obvious approach to the same character. The firm and mighty mass that constitutes the pyramids of Egypt has resisted the assaults of time and of tempests for, perhaps, upwards of four thousand years, and by many critical antiquaries is supposed to have triumphed over the deluge itself. While there is little doubt that the hard and closely crystallized granitic mountains of every country in which they occur, "the everlasting hills," to copy a correct and beautiful figure from the pages of Hebrew poetry, are coeval with the creation, and form at this moment, as they formed at first, the lowest depths as well as the topmost peaks of the globe. That they are in every instance considerably attenuated and wasted away admits, indeed, of no doubt; but

to have borne the brunt of so long and incessant a warfare, without actually being worn down to the level of the circumjacent plains, affords no feeble proof of an almost imperishable nature, and a proof open to the contemplation of the most common capacities.

There are various examples of the Macedonian stater or gold coin, struck in the reign of Philip, at this time preserved in the rich cabinet of the Florence gallery *, which, though they have continued in existence for at least 2200 years, do not appear to have lost any thing of their weight. Barthelemi, making a trivial mistake in the weight of the drachma, which he calculated at 66.55 grains English, suspected that these had sustained upon the average a loss of about seven-eighths of a grain during this long period; but as M. Fabbroni has since satisfactorily proved that the drachma was not more than 66.8 grains, and as this is the actual weight of several staters in this cabinet, we have a demonstration that they have sustained no diminution whatever.

Yet, in its liquid and gasseous state, matter often exhibits still more extraordinary instances of indestructibility or resistance to decomposition; and it should be especially remarked, that its indestructibility or indecomposable power appears to hold a direct proportion to its subtilty, its levity, its activity, its refined etherial or spiritualized modification of being.

* See Nicholson's Journal, vol. xxxii. p. 25.

Water is as much a compound as any of the earths, yet we have strong reason for believing that for the most part it exists unchangeably from age to age; and that its integrity has been not essentially interfered with from the commencement of the world. Its constituent parts are by no means broken into, but continue the same, whether under a solid form, as that of ice; under its usual form, as that of a liquid; or under an elastic form, as that of vapour: it is the same in the atmosphere as on the earth; it falls down of the very same nature as it ascends, and the electric flash itself appears, generally speaking, to have no other influence upon it than that of hastening its precipitation. It is only to be decomposed, that we know of, by a very concentrated action of the most powerful chemical agents; and even this, whether by art or by nature, upon a very limited scale.

A similar identity appears to exist in atmospheric air, which is, probably, at least as indestructible as water; for its composition, when purged of the heterogeneous substances which are often combined with it, is the same in the deepest valleys, as on the highest cliffs; at the equator, and at the poles; the earth's surface, and the height of 21,000 feet * above it: in many of which situations, and especially the more elevated, it is impossible for it ever to be generated; since the constituent parts of which it is

* See Thomson's Chem. vol. iv. 64, as also Phil. Mag. xvi 225.

composed are not found to exist in a separate state for its production. It is capable, indeed, of decomposition; but, like water, becomes decomposed with great difficulty, and probably consists at this moment, as to its general mass, of the very identic particles that formed it on its first emerging from a state of chaos.

Of the composition of the subtler gasses we know nothing. The specific weight of several of them has been ascertained, and the constituent principles of one or two of them, as nitrogene and hydrogene, have been guessed at, but nothing more; for the boldest experiments of chemistry have hitherto been exerted in vain to effect their decomposition. While as to those which are more immediately connected with the principle of animal life, and upon which many schools of modern philosophy have supposed it altogether to depend, as caloric, and the electric and voltaic fluids, the last of which seems in truth to be only a peculiar modification of the second, together with other substances or qualities which in subtilty and activity have a considerable resemblance to them, as light and the magnetic aura, we are not only wholly incapable of decomposing them by any process whatever, but even of determining them to be ponderable, or to possess any of the other common properties of matter, as extent and solidity. Whence we are, in fact, incapable of ascertaining whether they be matter at all, whether mere qualities of matter,

or whether some other more subtle and spiritualized substances *, intermixing themselves under different combinations with the material mass, and giving birth to many of its most extraordinary properties and phænomena.

The question is entered upon at some length by Professor Berzelius, in his "Explanatory Statement," published in the Memoirs of the Academy of Stockholm for 1812, in which he endeavours to support the probability that the electric fluids and caloric are material as well as the fluid of light; but, to do this, he is compelled to alter the common definition of matter, and to contend that matter does not necessarily possess gravitation or aggregation. †

The materiality of light has been attempted to be proved by its effects on solutions of muriate of ammonia and prussiate of potash, when placed in a situation to be crystallized. The crystallization of these salts may be directed at pleasure by the introduction of light at one or the other side of the vessels containing such solutions. Camphor displays a like affinity for light. All this, however, shows merely that light possesses an influence of some kind; but it by no means establishes that such influence is a material one. ‡

* See Young's Lectures, vol. ii. p. 742. lect. lx.

† See Nicholson's Journal, vol. xxxiv. p. 164, 165.

‡ See Accum's Elements of Crystallography, and Tilloch's Phil. Mag. vol. xli. p. 367.

Is it enquired to what important point these abstruse speculations lead? I may reply, among others, to the following:

First to a probability, if not to a proof, that matter, under peculiar modifications, is capable of making an approximation to something beyond itself, as ordinarily displayed; and hereby of becoming fitted, whenever necessary, for an intercourse and union with an immaterial principle.

And, secondly, to a clearer view of the coincidence of natural phænomena with one of the most glorious discoveries of revelation. For notwithstanding that matter, under every visible shape and texture, is at present, in a greater or less degree, perpetually changing and decomposing, the moment we perceive that this is not a necessary effect, dependent upon its intrinsic nature, but a beneficial power superadded to it for the mere purpose of rendering it a more varied and more extensive medium of being, beauty, and happiness—the moment we find ground for believing, that in its elementary principles it is essentially solid and unchangeable; and that even in many of its compounds it is almost as much exempted from the law of change—we are prepared to contemplate a period in some distant futurity, in which, the great object for which it has been endowed with this superadded power being accomplished, the exemption may extend equally to every part and to every compound: a period in which

there will be new heavens and a new earth, and whatever is now corruptible will put on incorruption.

But what, after all, is matter in its elementary principles, as far as we are capable of following them up? Can it be divided and subdivided to infinity? or is there a limit to such divisibility, beyond which the process cannot possibly proceed? and if so, are the ultimate bodies into which it is capable of dissolving still susceptible of developement, or, from their attenuation, removed beyond all power of detection?

These are questions which have agitated the world in almost all ages, and have laid a foundation for a variety of theories, of too much consequence to be passed over in a course of physical investigation.

The tenet of an infinite divisibility of matter, whether in ancient or modern times, appears to have been a mere invention for the purpose of avoiding one or two self-contradictions supposed to be chargeable upon the doctrine of its ultimate and elementary solidity; but which, I much fear, will be found to have given birth to far more self-contradiction than it has removed. The mode of reasoning, however, by which this tenet was arrived at in ancient Greece, was essentially different from that by which it has been arrived at in our own day.

It being, as we observed in our last lecture, an uncontroverted maxim among all the Greek

philosophers, of every sect and school whatever, that nothing could proceed from nothing, matter was of course conceived to have existed eternally, or it could not have existed at all. But it appeared obvious to most of them, that matter is as certainly unintelligent as they conjectured it is certainly eternal. The existence of intelligence, however, is still more demonstrable throughout nature than the existence of matter itself; and hence such philosophers were driven to the acknowledgement of an intelligent principle distinct from a material substance; and from the union of these two powers they accounted for the origin of the world: matter being merely passive and plastic, and put into form and endowed with the qualities and properties of body by the energy of the intelligent agent. But if form and corporeal properties have been communicated to it, it must, before such communication, and in its first or primal state, have been destitute of form; and that it was thus destitute is incontrovertible, continued the same schools of philosophy, because form presupposes the existence of intelligence, and must be, under every shape and modification, the product of an intelligent energy; for it is impossible that matter could have had a power of assuming one mode of form rather than another mode: since, if capable of assuming any kind, it must have been equally capable of assuming every kind, and, of

course, of exhibiting intelligent effects without an intelligent cause, which would be utter nonsense.

Such is the general train of reasoning that seems to have operated upon the minds of Pythagoras, Plato, and Aristotle, in impelling them to the belief that matter, in its primary state, to adopt the words of Cicero, in which he explains the Platonic doctrine, "is a substance without form or quality, but capable of receiving all forms, and undergoing every kind of change; in doing which, however, it never suffers annihilation, but merely a solution of its parts, which are in their nature infinitely divisible, and move in portions of space which are also infinitely divisible." *

But if we abstract from matter form and quality, and at the same time deny it intelligence, what is there left to constitute it an eternal substance of any kind? and by what means could pure incorporeal intelligence endow it with form?

These difficulties are insuperable; and, though attempted to be explained in different ways by each of these philosophers, they press like millstones upon their different systems, and are perpetually in danger of drowning them. Pythagoras compared the existence of matter, in its primary and amorphous state, to pure arithmetical numbers, before they are rendered visible by arithme-

Acad. Quæst. lib. i. cap. 8.

tical figures. "*Unity*," says he, "and *one* (the former of which he denominated *monad*) are to be distinguished from each other: *unity* is an abstract conception, resembling primary or incorporeal matter in its general aggregate; *one* appertains to things capable of being numbered, and may be compared to matter rendered visible under a particular form." So again, "Number is not infinite any more than matter; but it is nevertheless the source of that infinite divisibility into equal parts which is the property of all bodies." *

Numbers, however, were not more generally had recourse to by Pythagoras, to typify elementary matter under different modifications, than they are in the present day by the most elaborate chemists, to express its particular combinations: "As in all well-known compounds," observes Sir Humphry Davy, "the proportions of the elements are in certain definite ratios to each other, it is evident that these ratios may be expressed by numbers." † In consequence of which they are so expressed in various places by himself, and by many French, Swedish, and English chemists, the hint having been first suggested, I believe, by Higgens or Dalton. And hence the doctrine of numbers is well

* Anon. Photii, lib. c. Nicomac. apud Phot. Themist. in Phys. lib. iii. sect. 25. p. 67. See also Enfield's Brucker, i. b. ii. ch. 12. p. 383.

† Davy, Elem. i. p. 112.

known to have been very largely and very repeatedly had recourse to under the Pythagorean system, and to have been used in explanation, not only of the endowment of different portions of matter with different forms, but of the harmony with which the different natures of matter and mind unite in identic substances. Numbers and forms are, in consequence, not unfrequently contemplated as the same thing—as the models or archetypes after which the world in all its parts is framed—as the cause of entity to visible beings: τοῦς ἀριθμους αἰτίους εἶναι τῆς οὐσίας. *

And hence, again, under the term monad, or unity, Pythagoras is generally conceived to have symbolised God, or the active principle in nature; under duad, the passive principle, or matter; and under triad, the visible world, produced by the union of the two former.

Pythagoras, however, was as much attached to music as to numbers, regarding it as a mere branch of the science of numbers applied to a definite object. He has, indeed, the credit of having invented the monochord, and of having applied the principles of music, as well as those of numbers, to the study of physics. He conceived that the celestial spheres, in which the planets move, striking upon the elastic ether through which they pass, must produce a sound, and a

* Arist. Met. lib i. c. 6. Plut. Plac. Phil. lib. i. cap. 3. Athenag. Apol. 49.

sound that must vary according to the diversity of their magnitude, velocity, and relative distance; and, as the adjustment of the heavenly bodies to each other is perfect in every respect, he farther conjectured, that the harmony produced by their revolutions must also be the most perfect imaginable: and hence the origin of a notion, which is now, however, only entertained in a figurative sense, a sense frequently laid hold of by our own poets, and thus exquisitely enlarged on by Dryden: —

From harmony, from heav'nly harmony,
This universal frame began.
When nature underneath a heap
Of jarring atoms lay,
And could not heave her head,
The tuneful voice was heard from high,
Arise, ye more than dead!
Then hot and cold, and moist and dry,
In order to their stations leap,
And Music's power obey.
From harmony, from heav'nly harmony,
This universal frame began;
From harmony to harmony
Through all the compass of the notes it ran,
The diapason closing full in man.

What Pythagoras thus called numbers Plato denominated *ideas*, a term which has, hence, descended to our own day, and is on every one's lips, although in a different sense from what it originally imported. The reason or wisdom of the great First Cause, and which he denominates the logos of God, ὁ λογος, or ὁ λογίσμος τοῦ Θεοῦ, and

not unfrequently Δημιουργος (Demiurgus), Plato describes as a distinct principle from the Original Cause or Deity himself, from whom this efficient or operative cause, this divine wisdom or logos, emanates, and has eternally emanated, as light and heat from the sun. Thus emanating, he conceived it to be the immediate region or reservoir of ideas or intellectual forms, of the archetypes or patterns of things, subsisting by themselves as real beings — τὰ ὄντως ὄντα — in this their eternal and original well-spring; and the union of which with the whole, or any portion of primary or incorporeal matter, immediately produces palpable forms, and renders them objects of contemplation and science to the external senses.*

It is, hence, obvious that Plato contended for a triad or trinity of substances in the creation of the visible universe — God, divine wisdom, or the eternal source of intellectual forms or ideas, and incorporeal matter. And it is on this account that several of the earliest Christian fathers, who, as I have already observed, had been educated in the Platonic school, and had imbibed his notions, regarded this doctrine as of divine origin; and endeavoured, though preposterously, to blend the trinity of Plato, and that of the Christian scripture, into one common dogma: an attempt which has been occasionally revived in modern times, especially by Cud-

* Plac. Phil. lib. i. cap. x. Tim. lib. c.

worth and Ogilvie, with great profundity of learning and great shrewdness of argument, but, at the same time, with as little success as in the first ages of Christianity.

It is to this theory, which, indeed, is highly fitted for poetry, and much better so than for dry, dialectic discussion, Akenside beautifully alludes in the first book of his "Pleasures of Imagination:" —

Ere the radiant sun
Sprang from the east, or, mid the vault of night
The moon suspended her serener lamp;
Ere mountains, woods, or streams adorn'd the globe,
Or Wisdom taught the sons of men her lore;
Then liv'd th' Eternal One: then, deep retir'd
In his unfathom'd essence, view'd the forms,
The forms eternal of created things:
The radiant sun, the moon's nocturnal lamp,
The mountains, woods, and streams, the rolling globe,
And Wisdom's mien celestial. From the first
Of days, on them his love divine he fix'd,
His admiration; till, in time complete,
What he admir'd and lov'd his vital smile
Unfolded into being. Hence the breath
Of life in forming each organic frame;
Hence the green earth, and wild resounding waves;
Hence light and shade alternate; warmth and cold;
And clear autumnal skies, and vernal showers;
And all the fair variety of things.

While, however, we thus point out the fancifulness and imperfections of these hypotheses, let us, with the candour of genuine philosophy, do justice to the merits of their great inventors, and join in the admiration which has been so duly bestowed upon them by the wise and

learned of every country. It was Plato who first suggested to Gallileo, even upon his own confession, that antagonist power by which a rectilinear motion can be converted into an orbicular, and thus laid a basis for our accounting for the regular movements of the heavenly bodies *, a subject upon which we shall enter to a certain extent in our next lecture; who, in some degree, anticipated that correct system of colours which nothing but the genius of a Newton could fully develope and explain †; who in mathematics unfolded to us the analytic method of solving a problem ‡, and in theosophy so far surpassed all the philosophers of his country, in his correct views and sublime descriptions of the Deity, that he seems almost to have drunk of the inspiration of Horeb or of Sinai; and who, in his Timæus, applies to the wisdom of God, the λογισμὸς τοῦ Θεοῦ—a term which in Hebrew could scarcely be translated by any other word than that of Jeveh or Jehovah—πᾶς ὄντως ἀεὶ §, "WHATEVER IS ESSENTIALLY ETERNAL."

Of Pythagoras, it is only necessary to direct the attention to the two following very extraordinary facts, to place him beyond the reach of panegyric; the first of which has occasionally

* Galilei Discorsi è Dimostrazioni Matematiche, p. 254. 4to. Leyd. 1638. Dutens, Origine des Decouvertes, &c. p. 90. 4to. Lond. 1796.

† Plut. de Placitis Philos. lib. i. cap. 15. p. 32. Dutens, ut supr. p. 101.

‡ Dutens, ut supr. p. 251.

§ Plutarch. in Tim. lib. iii. 34. 37.

furnished reflection for other writers, though the latter remains unnoticed to the present moment. At an antedate of two thousand two hundred years from the age of Copernicus, this wonderful genius laid the first foundation of the Copernican system, and taught to his disciples that the earth revolves both around her own axis and around the sun; that the latter motion is conducted in an oblique path or zodiac *; and that the moon is an earth of the same kind as our own, and replete with animals, whose nature, however, he does not venture to describe.†

The second extraordinary fact to which I allude, is one we have already slightly glanced at, but which must not so cursorily be relinquished; I mean that, in ascribing to the primary or elementary forms of bodies, in their unions with each other, relative proportions so exact, yet so diversified, that forms and numbers may be employed as synonyms or convertible terms, he has exhibited so close a coincidence with one of the latest and most surprising discoveries of the present day, that though I dare not call it an anticipation, I am at a loss how else to characterise it: for it has

* Plutarch. de Placitis, lib. iii. cap. 11. 13. Diog. Laert. lib. viii. sect. 85. Copernicus himself admits that he derived his first hint of the earth's motion from Nicetas, a follower of Pythagoras. Vide his address to Paul III.

† Plutarch. de Placit. Cicer. Acad. Quæst. lib. iv. p. 984. col. 1. Something of this doctrine is to be found in the Orphic Hymn. Procl. de Orpheo, lib. iv. in Timæum, p. 154.

been minutely ascertained within the last ten or twelve years, by an almost infinite variety of accurate and well-defined experiments by Higgens, Dalton, Gay Lussac, and Davy, that the combinations and separations of all simple bodies are conducted in a definite and invariable ratio of relative weight or measure *; as that of one part to one part, one part to two parts, one to three, or one to four; and, consequently, that every change in the compound thus produced, whether of addition or diminution, is a precise multiple or divisor of such ratio; or, in other words, that the different elementary bodies which enter into such compounds can never unite or separate, never lay hold of or let go each other, in any other proportions.

Let us exemplify this remark by a familiar instance or two. It is now well known to every one, that the calxes, oxydes, or, as they are often called, rusts, of metals, consist of a certain portion of oxygene with a certain portion of the metal, which is thus converted into a calx or oxyde. It is also known in the present day to most persons, that the greater number of metals are possest of two or more kinds of oxydes, produced by an union of different proportions of the oxygene and the metal, and often distin-

* The only apparent exception I am aware of to this general principle is in the combination of the elements of M. Dulong's detonating substance, or azotane, as described by Sir Humphry Davy, Phil. Trans. for 1813, p. 250: and it is, hence, probable that we are not yet put into possession of the proper results.

guishable even by their colour; as minium or red lead, and cerusse or white lead, which are equally oxydes of the metal whose name they bear. Now, in whatever proportion the oxygene unites with the metal to produce an oxyde of one kind, it invariably unites by a multiple or divisor of the same proportion to produce every kind of oxyde belonging to the same metal. Thus we have discovered not less than four different oxydes of antimony in different parts of the world: the lowest or simplest of them contains 4½ parts of oxygene to 100 parts of metal; the next simplest contains 18 parts of oxygene to 100 parts of metal, which is four times 4½; the third oxyde consists of 27 parts of oxygene to 100 parts of metal, which is six times 4½; and the fourth oxyde, 36 parts of oxygene to 100 parts of metal, which is eight times 4½. So tin, which possesses three discovered oxydes, has for its lowest the proportion of 7 parts of oxygene to 100 parts of metal; for its second oxyde, 14 parts of oxygene to 100 parts of metal, which is twice 7; and for its highest, 21 parts of oxygene to 100 parts of metal, which is three times 7. I have given the proportions in round numbers; but if I were to use the fractions that belong to them, the comparative results would be precisely the same. Nor can we possibly combine these substances in any other proportions so as to produce oxydes, for the corpuscles of which they consist will not lay hold of or let go each other in any other ratios. It is possible that we may

hereafter detect an oxyde of antimony consisting of a less proportion of oxygene than 4½; but if we ever should, we are confident beforehand that such proportion will be 2¼. It is also possible that we may meet with an oxyde containing more than 4½ and less than 18 parts of oxygene in 103; but if we should do so, we can nearly anticipate that such proportion will be 9. And hence, as these proportions, though constantly true to their respective series, are constantly diversified in different substances, their radical figures or numbers may be employed, and now actually are employed, and that very generally, and in perfect coincidence with the system of the Pythagorists, as synonyms of the simple forms or substances whose progressive character they describe. This curious coincidence of ancient and modern philosophy, for at present I will call it nothing more, I cannot but regard as a very marvellous fact; and am not a little surprised that it should not hitherto have occurred, as it does not appear to have done, to the minds of any of those learned and ingenious chemists who have chiefly been employed in applying and building up the discovery. And it is not the least important part of this discovery, that not only in the union or separation of simple substances, but in all well known and more complicated compounds, so far as the experimental series has been carried, the elementary bodies which enter into them exhibit proportions equally definite and invariable; thus affording another

proof of close connexion between the phænomena of nature and the occasional developements of revelation; the philosopher beholding now, as the prophet beheld formerly, that the Almighty Architect has literally adjusted every thing by weight and measure; that he has measured the waters and meted out the heavens, accurately comprehended the dust of the earth, weighed the mountains in scales and the hills in a balance.

LECTURE III.

ON THE ELEMENTARY AND CONSTITUENT PRINCIPLES OF THINGS.

(The subject continued.)

THE few steps we have hitherto taken in the wide and magnificent scope before us have only led to an establishment of two or three fundamental axioms, of no small importance in the science of physics, and to a developement of two or three of the most ingenious and most popular hypotheses of former times, invented to account for the origin of the world around us, and the elementary and constituent principles of things; especially the hypothesis of numbers, as proposed by Pythagoras, and that of ideas, as proposed by Plato; and their application to primary and incorporeal matter, in order to endow it with form and quality. There are yet two or three other hypotheses upon the same subject that amply demand our attention, and are replete with an equal degree of ingenuity and fine imagination; especially the Peripatetic and the Atomic, or that of Aristotle and that of Epicurus; and we have also to trace out the relative degree of influence which each of these has exerted on the philosophical theories of later times.

Aristotle had too much penetration not to see that the hypothesis of Plato was just as inadequate as that of Pythagoras to a solution of the great question concerning the production of the visible world: and he proposed a third scheme, which has also had its share of popularity. According to this remodelled plan, the sensible universe is the result of four distinct principles,—intelligence, matter, form, and privation; which last term is little more than a mere synonym for space or vacuum; and thus far the theory of Aristotle chiefly differs from that of Plato, by interweaving into it his fourth principle, derived from Democritus, and the other Atomic philosophers, and which he seems to have added to it with a view of providing a proper theatre for the two principles of form and matter to move in. He supposes all these to have equally existed from eternity; and the three last to have been eternally acted upon or thrown into a definite series of motions, upon which alone the existence and harmony of things are dependent, by the immutable and immaterial principle of intelligence, whose residence he places in the purest and loftiest sphere or circle of the heavens; a sphere that in its vast embrace comprehends ten lower or subordinate spheres, that lie between itself and the earth, which forms the centre of the whole, and, in conjunction with the earth, constitutes the universal world.

This supreme intelligence Aristotle conceived to be in himself for ever at rest; and the tranquil

and peaceable sphere in which he resides he denominated the empyreum or heaven of bliss. But though enjoying eternal rest himself, he communicates motion, necessarily and essentially, upon this theory, to the sphere immediately below him; as this, in its turn, communicates it in different directions, and with different velocities, to the other spheres that revolve within its range *; whence the sphere thus earliest receiving motion, and nearest to the empyreum, Aristotle denominated the PRIMUM MOBILE or first moving power: it constituted the tenth in the regular series; the ninth, or that which lies next to it, being denominated the crystalline heavens; the eighth, the starry sphere, or heavens; and the remaining seven deriving their names from, and being appropriated to, the different revolutions of the different planets, as Saturn, Jupiter, Mars, Apollo or the sun, Venus, Mercury, and Diana or the moon: the earth, forming the centre of the whole, being an imperfect sphere, with a larger proportion of matter at the equator; on which account the earth was conceived to turn on her axis in a rocking motion, revolving round the axis of the ecliptic, and making the stars appear to shift their places at the rate of about one degree in seventy-two years. According to which calculation, all of them will appear to perform a complete revolution in the space of

* Diog. Laert. lib. v. sect. 23. Arist. Phys. lib. 1. cap. 3, 4. De Cæl. lib. 2. cap. 3. 11.

25,920 years, and, consequently, to return to the precise situation they occupied at the commencement of such period. This period was hence denominated the ANNUS MAGNUS, or GREAT YEAR, and not unfrequently the PLATONIC YEAR, as the same kind of revolution was in some measure taught also by Plato.

The motory power, thus impressed by the intelligent moving principle, not voluntarily but by necessity, upon the different heavenly spheres, and finally upon the earth, and productive of that catenation of effects which is equally without beginning and without end, Aristotle denominated NATURE, and thus furnished us with a word, which has for ages been so extensively made use of, that, though there is nothing in all language more imprecise, there is nothing we could spare with more inconvenience. The same term, indeed, is occasionally employed by Plato, but in a sense still less definite if possible, and at the same time still less comprehensive.

On the revival of literature, this theory, together with the other branches of Peripatetic science, was chiefly restored and studied; and continued, indeed, to be generally adhered to for upwards of a century after the publication of the Copernican system; which is well known to have at first experienced but a very cold and inhospitable reception from the literary world. And it is hence this theory that is principally adverted to and described in the productions of

all the early poets as well as philosophers of every part of modern Europe. And so complete was the triumph of the Peripatetic school in all its doctrines throughout Christendom, at this period, that Melancthon makes it a matter of complaint that, even in the sacred assemblies, parts of the writings of Aristotle were read to the people instead of the Gospel. Even Milton himself, though born considerably more than a century after Copernicus, wavers as to the propriety of adopting his hypothesis of the heavens, and hence, in his Paradise Lost*, leaves it doubtful which of the two, the new or the old, ought to be preferred. The best and most splendid description of the Aristotelian theory that I have ever met with is contained in the Lusiad of Camoens; the whole is too long for quotation, but I may venture to affirm, that you will be pleased with the following lines from Mr. Mickel's very spirited version of the Portuguese bard, as delineating the different heavenly spheres that were supposed, as I have already observed, to lie one within another, like the different tunics of an onion: —

These spheres behold: the first in wide embrace
Surrounds the lesser orbs of various face;
The EMPYREAN this, the holiest heaven,
To the pure spirits of the blest is given:
No mortal eye its splendid rays may bear,
No mortal bosom feel the raptures there.
The earth in all her summer pride array'd
To this might seem a dark, sepulchral shade.

* Book viii.

Unmov'd it stands.—Within its shining frame,
In motion swifter than the lightning's flame,
Swifter than sight the moving parts may spy,
Another sphere whirls round its rapid sky:
Hence MOTION darts its force, impulsive draws,
And on the other orbs impresses laws. *

These hypotheses are abstruse, and perhaps ill calculated to afford amusement; but in a course of physical study they ought by no means to be overlooked. Abstruse as they are, the one or the other of them is interwoven with the whole range of classical literature, and, as I have already remarked, held the ascendant in the horizon of metaphysics till within the last two centuries; and I have dwelt upon them the rather, because, much as we still hear of them, and find them adverted to in books, I am not acquainted with any work whatever that gives any thing like a clear and intelligible summary of their principles. Their more prominent defects are, in few words, as follows: Independently of conveying very imperfect and erroneous views of the creation, they equally concur in reducing matter, notwithstanding its pretended eternal existence, to a non-entity, and confound its properties with those of pure intelligence, by giving to numbers, ideas, or a mere abstract notion, real form and existence. The most powerful advocate of the Platonic theory, in modern times, was the very excellent Bishop

* Book x. p. 443. 4to. 1776.

Berkeley; who, in the true spirit of consistency, and with a boldness that no consequences could deter, openly denied the existence of a material world, and thus reduced the range of actual entities from three to two, an intelligent first cause, and intellectual forms or ideas, and gave the death-blow to the system, by avowing its necessary result.

In modern times, however, as I have already hinted at, the infinite divisibility of matter has for the most part been supported upon different grounds, and philosophers have involved themselves in the same fatal consequences, by a much shorter process of reasoning. No compound or visible bodies, it is well known, ever come into immediate contact with each other, or influence each other by means of simple solidity. The earth is affected by the sun, the moon by the earth; the waters of the earth by the moon. Light is reflected from substances to which it directs its course at a distance, and without impinging upon them. The particles of all bodies deemed the most solid and impermeable, are capable of approaching nearer, or receding farther from each other, by an application of different degrees of cold or heat. We can, hence, it is said, form no conception of perfect solidity; and every phænomenon in nature appears to disprove its existence. The minutest corpuscle we can operate upon is still capable of a minuter division, and the parts into which it divides possessing the common nature

of the corpuscle which has produced them, must necessarily, it is added, be capable of a still farther division; and as such divisions can have no assignable limit, matter must necessarily and essentially be divisible to infinity.

Such was the reasoning of Des Cartes, and of the numerous host of philosophers who attached themselves to his theory about the middle of the seventeenth century. The argument, indeed, is highly plausible; but it was soon obvious, that, like the Grecian incorporiety of matter, it leads to a pure nonentity of a material world: for that which is essentially unsolid and infinitely divisible, must at length terminate in nothing. And hence, Leibnitz attempted to amend the system, about half a century, and Boscovich, about a century afterwards, by contending, as indeed Zeno is supposed to have done formerly, that matter has its ultimate atoms, or monads, as they were denominated by Leibnitz, from the language of Pythagoras, beyond which it is altogether indivisible; and that these ultimate atoms or monads are simple inextended points, producing, however, the phænomenon of extension, by their combination, and essentially possest of the powers of attraction and repulsion.

There is such a charm in novelty, that it often leads us captive in despite of the most glaring errors, and intoxicates our judgment as fatally as the cup of Circe. It is upon this

ground alone we can account for the general adoption of this new system, when first proposed in its finished state by Boscovich, and the general belief that the Gordian knot was at length fairly untied, and every difficulty overcome. It required a period of some years for the heated imagination to become sufficiently cool to enable mankind to see, as every one sees at present, that the difficulties chargeable upon the doctrine of an infinite divisibility of matter are not touched by the present theory, and remain in as full force as before its appearance. If the monads, or ultimate points of matter here adverted to, possess body, they must be as capable of extension, and consequently of division, as material body under any other dimension or modification: if they do not possess body, then are they as much nonentities as the primal or amorphous matter of Plato or Pythagoras. Again, we are told that these points or monads are endowed with certain powers; as those, for example, of attraction and repulsion. But powers must be the powers of something; what is this something to which these powers are thus said to appertain? if the ultimate and inextended points before us have nothing but these powers, and be nothing but these powers, then are such powers powers of nothing, powers without a substrate, and, consequently, as much nonentities as on the preceding argument. Visible or sensible matter, moreover, it is admitted by M. Boscovich and his disciples, is possessed of

extension; but visible or sensible matter is also admitted to be a mere result of a combination of inextended atoms:—how can extension proceed from what is inextended?—of two diametrical opposites, how is it possible that either can become the product of the other?

It is unnecessary to pursue this refutation. The lesson which the whole of such fine-spun and fanciful hypotheses teach us, and teach us equally, is, that it is impossible to philosophise without a firm basis of first principles. We must have them in physics as well as in metaphysics,—in matter as well as in morals; and hence the best physical schools in Greece, as well as in more modern times,—those which have contended for the eternity of matter, as well as those which have contended for its creation out of nothing,—have equally found it necessary to take for granted, what in fact can never be proved, that matter in its lowest and ultimate parts consists of solid, impenetrable, and moveable particles, of definite sizes, figures, and proportions to space; from different combinations of which, though invisible in themselves, every visible substance is produced.

This theory, which has been commonly distinguished by the name of the Atomic philosophy, was first started in Greece by Leucippus or Democritus, and afterwards considerably improved by Epicurus; and as it bears a striking analogy to many of the features which mark the best opinions of the present day, and has

probably given them much of their colour and complexion, if it have not originated them, I shall take leave to submit to you the following outline of it:—*

The Atomic philosophy of Epicurus, in its mere *physical* contemplation, allows of nothing but matter and space, which are equally infinite and unbounded, which have equally existed from all eternity, and from different combinations of which every visible form is created. These elementary principles have no common property with each other: for whatever matter is, that space is the reverse of; and whatever space is, matter is the contrary to. The actually solid parts of all bodies, therefore, are matter; their actual pores space; and the parts which are not altogether solid, but an intermixture of solidity and pore, are space and matter combined. Anterior to the formation of the universe, space and matter existed uncombined, or in their pure and elementary state. Space, in its elementary state, is absolute and perfect void; matter, in its elementary state, consists of inconceivably minute seeds or atoms, so small that the corpuscles of vapour, light, and heat are compounds of them; and so solid, that they cannot possibly be broken or abraded by any concussion or violence whatever. The express figure of these primary atoms is various: there are round, square, pointed, jagged as well as

* This outline is given more at length in the author's Prolegomena to his translation of "The Nature of Things," p. cix. and following.

many other shapes. These shapes, however, are not diversified to infinity; but the atoms themselves of each existent shape are infinite or innumerable. Every atom is possessed of certain intrinsic powers of motion. Under the old school of Democritus, the perpetual motions hence produced were of two kinds: a descending motion, from the natural gravity of the atoms; and a rebounding motion, from collision and mutual clash. Besides these two motions, and to explain certain phænomena to which they did not appear competent, and which were not accounted for under the old system, Epicurus supposed that some atoms were occasionally possessed of a third, by which, in some very small degree, they descended in an oblique or curvilinear direction, deviating from the common and right line anomalously; and in this respect resembling the oscillations of the magnetic needle.

These infinite groups of atoms, flying through all time and space in different directions, and under different laws, have interchangeably tried and exhibited every possible mode of rencounter; sometimes repelled from each other by concussion, and sometimes adhering to each other from their own jagged or pointed construction, or from the casual interstices which two or more connected atoms must produce, and which may be just adapted to those of other figures, as globular, oval, or square. Hence, the origin of compound and visible bodies; hence, the

origin of large masses of matter; hence, eventually, the origin of the world itself. When these primary atoms are closely compacted, and but little vacuity or space lies between, they produce those kinds of substances which we denominate solid, as stones and metals; when they are loose and disjoined, and a large quantity of space or vacuity is interposed, they exhibit bodies of lax texture, as wool, water, vapour. In one mode of combination, they form earth; in another, air; and in another, fire. Arranged in one way, they produce vegetation and irritability; in another way, animal life and perception. Man hence arises, families are formed, societies are multiplied, and governments are instituted.

The world, thus generated, is perpetually sustained by the application of fresh tides of elementary atoms, flying with inconceivable rapidity through all the the infinity of space, invisible from their minuteness, and occupying the posts of those that are as perpetually flying off. Yet nothing is eternal or immutable but these elementary seeds or atoms themselves. The compound forms of matter are continually decomposing and dissolving into their original corpuscles; to this there is no exception: minerals, vegetables, and animals, in this respect all alike, when they lose their present make, perishing for ever, and new combinations proceeding from the matter into which they dissolve. But the world itself is a compound though not an organized being; sustained and nourished, like organized beings,

from the material pabulum that floats through the void of infinity. The world itself must, therefore, in the same manner, perish: it had a beginning, and it will have an end. Its present crasis will be decompounded; it will return to its original, its elementary atoms; and new worlds will arise from its destruction.

Space is infinite, material atoms are infinite, but the world is not infinite. This, then, is not the only world, nor the only material system that exists. The cause that has produced this visible system is competent to produce others: it has been acting perpetually from all eternity; and there are other worlds, and other systems of worlds, existing around us.

Those who are acquainted with the writings of Sir Isaac Newton and Mr. Locke will perceive in this sketch of the Atomic philosophy the rudiments of a very great part of their own systems, so far as relates to physics; we may, indeed, fairly regard them as offsets from the theory before us, cleared in a very great degree of its errors, and enlarged in their principles, and fortified by more recent observations and discoveries. I must, for the present, confine myself to the following quotations from the first of these high ornaments of our country. "All things considered," says Sir Isaac, "it seems probable that God, in the beginning, formed matter in *solid, massy, hard, impenetrable, moveable particles; of such sizes and figures,* and with such *other properties,* and in such *propor-*

tion to space, as most conduced to the end for which he formed them." So again: "While the primitive and solid particles of matter continue entire, they may compose bodies of one and the same nature and texture in all ages; but should they wear away, or break in pieces, the nature of things depending on them would be changed. Water and earth, composed of old worn particles and fragments of particles, would not be of the same nature and texture now, with water and earth composed of entire particles at the beginning; and therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the *various separations*, and *new associations* and *motions* of these permanent particles: compound bodies being apt to break, not in the midst of solid particles, but where those particles are laid together, and touch only in a few points."

The Epicurean doctrine, moreover, of a flux and reflux of elementary particles exterior to every material system, perpetually feeding and replenishing it, and carrying off its dissolved and rejected rudiments, bears no small resemblance to the ethereal medium of Sir Isaac Newton; and, in its law of action, has been singularly revived within the course of the last six years by Professor Leslie, in his principles of impulsion, as detailed in his "Inquiry into the Nature of Heat." It is a doctrine, also, peculiarly coincident with Dr. Herschel's recent theory of nebulæ, or milky ways in the heavens, which,

contrary to his own earlier opinions, and those of former astronomers, who ascribed such appearance to the mixt light thrown forth from clusters of stars too remote to be reached by the best telescopes, he now resolves, as we shall have occasion to show more minutely in due time, into masses of a luminous fluid, existing independently of all stars or planets, though originally, perhaps, emitted from them; aggregated by a variety of causes that tend to give its minute particles unity; sometimes forming new stars by its condensation, and often feeding and regenerating those that are exhausted.

Such is a brief survey of the chief theories of the primitive or elementary substance of matter which have been offered in ancient or modern times; from a combination of the different particles of which, in different modes and proportions, and under the operation of different laws, all sensible bodies are supposed to have proceeded.

Of sensible bodies thus produced, some, however, in direct repugnancy to the Atomic philosophy, whether of ancient or more recent times, have been very generally conceived to have been formed first; to be peculiarly simple in their composition, indecomposable by any known powers in their structure, and to be the basis of all other bodies, or those from which all other bodies proceed, by different unions and modifications: and hence such substances have been denominated *constituent principles*, or *constituent elements*; concerning the kind and number

of which, however, we have had almost as many opinions offered as concerning the origin and nature of the primitive principles themselves.

Thus, among both the ancients and the moderns, sometimes fire, sometimes air, sometimes earth, and sometimes water, has been considered as the sole constituent element or source of things. Sometimes two of these substances have been thus denominated, and sometimes three; but more generally the whole. Occasionally, indeed, a fifth, and even a sixth, have been added to the number, as cold and oil, each of these having at times been considered as simple and indecomposable substances: while, under the old Atomic system, and especially as improved by Epicurus, all such principles were completely swept away, and no one sensible substance whatever was conceived to be better entitled to the character of a constituent principle than another; the whole equally flowing from peculiar modifications and combinations of the primitive or elementary principles — the RERUM PRIMORDIA — and equally resolving into them upon decomposition.

Of these different theories, the greater number are scarcely worth examining; and I shall only therefore observe, that for that which supposes the existence of four distinct elements, fire, air, earth, and water, and which for ages has been in almost universal acceptation, and would have been so still but for the recent discoveries of chemistry, we are indebted to

Empedocles. This celebrated philosopher, and very excellent poet, flourished about four centuries before the Christian æra. His opinions, like those of almost all the earliest sages, were given in metre, in a didactic poem, "On Nature," of which only a few fragments have descended to our own times. He was a native of Sicily, and his talents and his country are celebrated by Lucretius, who was nevertheless of a very different school of philosophy, in verses so elegant and so descriptive, that I cannot refrain from presenting you with a literal but very humble translation of them; introduced, more especially, as they are, with observations upon different rival philosophers, who employed one, two, and various other numbers of the commonly esteemed elements, and in various combinations, as the basis of their respective theories.

Nor wanders less the sage who AIR with FIRE
Would fain commix, or limpid STREAM with EARTH;
Or those the whole who join, FIRE, ETHER, EARTH,
And pregnant SHOWERS, and thence the world deduce.
Thus sung EMPEDOCLES, in honest fame
First of his sect; whom AGRIGENTUM bore
In cloud-capt SICILY. Its sinuous shores
Th' IONIAN main, with hoarse, unwearied wave,
Surrounds, and sprinkles, with its briny dew:
And, from the fair ÆOLIAN fields, divides
With narrow frith that spurns th' impetuous surge.
Here vast CHARYBDIS raves: here ÆTNA rears
His infant thunders, his dread jaws unlocks,
And heav'n and earth with fiery ruin threats.
Here many a wonder, many a scene sublime,

As on he journeys, checks the traveller's steps;
And shows, at once, a land in harvests rich,
And rich in sages of illustrious fame.
But nought so wond'rous, so illustrious nought,
So fair, so pure, so lovely, can it boast,
EMPEDOCLES, as thou! whose song divine,
By all rehears'd, so clears each mystic lore,
That scarce mankind believ'd thee born of man.
Yet e'en EMPEDOCLES, and those above
Already sung, of far inferior fame,
Though doctrines frequent from their bosoms flow'd
Like inspiration, sager and more true
Than e'er the PYTHIAN maid, with laurels crown'd,
Spoke from the tripod at APOLLO's shrine;
E'en those mistook the principles of things,
And greatly wander'd in attempt so great.

Let our controvertists of the present day learn a lesson of liberality from this correct and polished reasoner, whose own theory is well known to have been that of Epicurus, to which I have just adverted, namely, that one substance is just as much entitled to the character of a constituent element as another,—and that every thing equally proceeds from and in turn is resolved into the primitive and invisible atoms or principles of matter.

It is to this theory alone that all the experiments of modern chemistry are giving countenance. Air, water, and earth suspected to be compounds in the time of Epicurus, have been proved to be such in our own day; while of the actual nature of heat or fire, mankind are just as uninformed now as they were then.

In the process, however, of destroying these supposed elements, chemistry has occasionally

seemed to detect others; and hence, instead of air, fire, earth, and water, as simple or indecomposable substances, we have had phlogiston, acids, and alkalies; sulphur and phosphorus; oxygene, hydrogene, nitrogene, and carbone, progressively arising before us, and laying claim to an imperishable existence. All of them, however, have fallen, or are falling in their turn, without having lived long enough to reach the common age of man; all of them have been proved, or reasonably suspected, to be compounds of other substances, that may yet, perhaps, be detected to be compounds of something beyond. Even oxygene, the most brilliant of the whole, the boasted discovery of Lavoisier, and out of which he was supposed to have built to his own memory "a monument more durable than brass," has had its throne shaken to its foundation by Sir Humphry Davy, and is at this moment, like the Roman empire in its decline, obliged to divide its sway with a new and popular power, which this last celebrated chemist has denominated chlorine; while of the more subtle and active agents, light, caloric, the magnetic and electric fluids, we know nothing but from their effects, and can only say of each — *stat nominis umbra.*

Is physical science then a vain show? — a mere house of cards, built up for the sole purpose of being pulled down again? — Assuredly not. The firm footing we have actually obtained upon many essential points — a footing not to be disturbed by any future change of system, or novelty

of discovery—and the ascertainment of a multitude of recondite facts, and their application to some of our most extensive and valuable arts, sufficiently prove that philosophy has neither lived nor laboured in vain. Although we have not been able to break through the spell completely—to follow up the Proteus-form of matter into its deepest recesses, and fix it in its last shape and character—we have succeeded in developing many of its most important laws, as it will be the object of the ensuing lecture to point out, and to apply them to a solution of many of its most important phænomena. Whatever is sure and trusty has remained to us, and whatever has given way has been mere chimæra and shadow: we have chiefly, perhaps only, failed where we have either been too curious, or have suffered imagination to become our charioteer in the slow and sober journey of analysis.

Before we quit this subject, let us, in the candid spirit of genuine philosophy, do the same justice to Epicurus as we attempted in our last lecture to Pythagoras and Plato. It has been very generally said, and very generally believed, principally because it has been very generally said, that the great and mighty cause of this beautiful and harmonious formation of worlds, and systems of worlds, in the opinion of Epicurus, was mere CHANCE, OR FORTUNE. There is nothing, however, in those fragments of his works which have descended to us, that can in any way

countenance so opprobrious an opinion, but various passages that distinctly controvert it,—passages in which he peremptorily denies the existence of CHANCE or FORTUNE, either as a deity or a cause of action; and unequivocally refers the whole of those complex series of percussions and repercussions, interchanges and combinations, exhibited by the elementary seeds or atoms of matter during the creative process, to a chain of immutable laws which they received from the Almighty Architect at the beginning, and which they still punctually obey, and will for ever obey till the universe shall at length cease to exist.* "Whom," says Epicurus, in a letter to his disciple Menæceus, that has yet survived the preying tooth of time, and will be found in Diogenes Laertius, "do you believe to be more excellent than he who piously reveres the Gods, who feels no dread of death, and rightly estimates the design of nature? Such a man does not, with the multitude, regard CHANCE as a God, for he knows that God *can never act at random;* nor as A CONTINGENT CAUSE OF EVENTS; nor does he conceive, that from any such power flows the good or the evil that measures the real happiness of human life." He held, however, that the laws which govern the universe were altogether arranged and imposed upon it by the Creator at its first formation, and that the successive train

* For a more extensive inquiry into this subject, the reader is referred to the author's Prolegomena to his translation of "The Nature of Things," from which this summary is drawn

of events to which they have given rise have followed as the necessary result of such an arrangement, and not as the immediate superintendence of a perpetually controlling Providence. For it was the opinion of Epicurus, as well as of Aristotle, that perfect rest and tranquillity are essential to the perfect happiness even of Him, who, to adopt his own language in another place, possesses all immortality and beatitude. "Think not," says he, "that the different motions and revolutions of the heavens, the rising, setting, eclipses, and other phænomena of the planets, are produced by the *immediate* control, superintendence, or ministration of Him who possesses all immortality and beatitude; it is from the immutable laws which they received at the beginning, in the creation of the universe, that they punctually fulfil their several circuits."

The origin of this calumny upon the character of Epicurus it is by no means difficult to trace, and it has been sufficiently traced, and sufficiently exposed, by Diogenes Laertius, Gassendi, Du Rondelle, and other distinguished writers, who have done ample justice to his memory; and upon the confessions of Plutarch, Cicero, and Seneca, abundantly proved, that it was the same rancorous spirit of envy among many of his competitors for public fame, and especially among the Stoic philosophers, which strove to fix upon him the charge of voluptuous living, though the most temperate and abstemious Athenian of his day, that thus, with yet keener malevolence, endea-

voured to brand him with the still fouler reproach of the grossest impiety and atheism. It is indeed scarcely to be believed, if the fact were not concurrently attested by all the writers of antiquity, that the philosopher, whose name, from the low and malignant spirit I have just adverted to, has been proverbialised for general licentiousness and excess, drew the whole of his daily diet from the plainest pottage, intermixed with the herbs and fruits of his pleasant and celebrated garden. "I am perfectly contented," says he, in an epistle to another friend, "with bread and water alone; but send me a piece of your Cyprian cheese, that I may indulge myself whenever I feel disposed for a luxurious treat." Such, too, was the diet of his disciples. Water, says Diocles, was their common beverage; and of wine they never allowed themselves more than a very small cup. And hence, when the city of Athens was besieged by Demetrius, and its inhabitants reduced to the utmost extremity, the scholars of Epicurus bore up under the calamity with less inconvenience than any other class of citizens; the philosopher supporting them at his own expence, and sharing with them daily a small ration of his beans. The pleasure of friendship, the pleasure of virtue, the pleasure of tranquillity, the pleasure of science, the pleasure of gardening, the pleasure of studying the works of nature, and of admiring her in all the picturesque beauty of her evolutions, formed the sole pursuit of his life. This alone, he affirmed,

deserves the name of PLEASURE, and can alone raise the mind above the grovelling and misnamed pleasures of self-indulgence, debauchery, and excess.

There is something gratifying to an enlarged and liberal spirit in being thus able to rescue from popular, but unfounded obloquy, a sage of transcendant genius and almost unrivalled intellect, and in restoring him to the admiration of the virtuous and the excellent. That he did not feel the force of any argument offered by nature in proof of the immortality of the soul, and was in this respect considerably below the standard of Socrates and Cicero, must be equally admitted and lamented; and should teach us the high value of that full and satisfactory light which was then so much wanted, and has since been so gloriously shed upon this momentous subject. But let it at the same time be remembered, that, with a far bolder front than either of the philosophers here adverted to, he dared to expose the grossness and the absurdities of the popular religion of his day, and in his life and his doctrines gave a perpetual rebuke to vice and immorality of every kind. And hence, indeed, the main ground of the popular calumny with which his character was attacked, and which has too generally accompanied his memory to the present day.

LECTURE IV.

ON THE PROPERTIES OF MATTER, ESSENTIAL AND PECULIAR.

In our last lecture I endeavoured to render it probable, that all visible or sensible matter is the result of a combination of various solid, impenetrable, and exquisitely fine particles or units of the same substance, too minute to be detected by any operation of the senses. Of the shape or magnitude of these particles we know nothing: and even their solidity and impenetrability, as I then observed, is rather an assumption, for the purpose of avoiding several striking difficulties and absurdities that follow from a denial of these qualities, than an ascertained and established fact.

From this unsatisfactory view of it in its elementary and impalpable state, let us now proceed to contemplate it in its manifest and combined forms, and to investigate the more obvious properties they offer, and the general laws by which they are regulated.

The change of distance between one material body and another, or, in other words, their approach to or separation from each other, is called MOTION; and the wide expanse in which

motion of any kind is performed is denominated SPACE.

Matter has its ESSENTIAL, and its PECULIAR PROPERTIES. Its essential properties are those which are common to it under every form or mode of combination. Its peculiar properties are those which only appertain to it under definite forms or definite circumstances.

The ESSENTIAL PROPERTIES of matter are usually classed under the six following heads: passivity, extension, density, impenetrability, divisibility, and gravitation; which, however, may easily be reduced to four, since extension, density, and impenetrability may be comprehended under the general term cohesibility.

PASSIVITY, *inertia*, or *vis inertiæ*, is the tendency in a body to persevere in a given state, whether of rest or motion, till disturbed by a body of superior force. And hence these terms, which are mere synonyms, imply a power of mobility as well as a power of quiescence; although passivity has often been confined to quiescence, while mobility has been made a distinct property. Thus it is from the same power, or tendency to passivity, that a cannon-ball continues its motion after being projected from a gun, as that by which it remained at rest before it was thrown off; for it is a well-known theorem in projectiles, that the action of the powder on a bullet ceases as soon as the bullet is out of the piece. In like manner a billiard-ball at rest will continue so till put into motion by a

billiard-ball in motion, for it can never commence motion of its own accord. While a billiard-ball in motion would persevere in motion, and in the same velocity of motion, for ever, if it met with no resistance. But it does meet with resistance from a variety of causes, as the friction of the atmosphere, the friction of the green-cloth, and at last a contact with one of the sides of the table, or with the ball against which it is directed.

In this last case either ball will receive conversely the same precise proportion of rest or motion which it communicates. Thus, if the ball in motion strike the ball at rest obliquely, the latter will be put into a certain degree of activity, and the former will, in the very same degree, be impeded in its progress, and receive an equal tendency to a state of rest. If the latter, on the contrary, by what is significantly called a *dead* stroke, receive the whole charge of motion which belongs to the former, it will give to the former, in like manner, the whole possession of its quiescence, and the state of each will be completely reversed: the ball hitherto at rest proceeding with all the velocity of that hitherto in motion, and the ball hitherto in motion exhibiting the dead stand of that hitherto at rest.

So, if it were possible to place an orb quietly in some particular part of space, where it would be equally free from the attractive influence of every one of the celestial systems, it would, from

the same tendency to inertitude, remain quiescent and at rest for ever. While, on the contrary, if a body were to be thrown from any one of the planets by the projectile force of a volcano, or of any other agency, beyond the range of the attractive or centripetal power of such planet, it would continue the same velocity of motion for ever which it possessed at the moment of quitting the extreme limit of the planet's influence; unless in its progress it should encounter the influence of some other planet; and in this last case it would be either drawn directly into contact with the planet it thus casually approached, or would have its path inflected into a circle, and revolve around it as a satellite, according to its velocity, and the relative direction of its course at the moment the planetary influence began to take effect. Thus a body projected horizontally to the distance of about 4.35 miles from the earth's surface, provided there were no resistance in the atmosphere, would not fall back again, but become a satellite to the earth, and perpetually revolve around it at this distance. The moon is supposed to have no atmosphere, or, at the utmost, one rarer than we can produce with our best air-pumps: she is also supposed to possess larger and more active volcanos than any which are known to exist on the earth. And hence it requires no great stretch of imagination to conceive that bodies may occasionally be thrown from the moon, by the projectile power of such volcanos, to such a distance as that they

should never return to her surface: for if the momentum be only sufficient to cause the mass ejected to proceed at the rate of about 8,200 feet in the first second of time *, and in a line passing through the moon and the earth, such effect would necessarily be produced; since, in this case, the propelled mass would quit the centripetal power of the former, and be drawn into that of the latter, and would either become a satellite to the earth, or be precipitated to its surface, according as the rectilinear force of the projectile was equal or inferior to the attractive force of the earth at their first meeting together.

Yet this is, perhaps, but little more than the velocity with which a twenty-four pound cannon-ball would travel from the moon's surface: since its velocity on the earth's surface may be calculated at about 2,000 feet for the first second; and it would rush nearly four times as rapidly if not impeded by the resistance of the atmosphere. And hence it is to this cause that M. Olbers first, and M. Laplace has since, ascribed the origin of those wonderful aerolites, or stones, that are now known to have fallen from the air at some period or other in every quarter of the globe; believing them to be in every instance volcanic productions of the moon, thrown by the impulse of the explosion beyond the range of her centripetal influence.

* Laplace, Exposition du Système du Monde.

Cohesibility is the tendency which one part of matter evinces to unite with another part of matter, so as to form out of different bodies one common mass. It includes the three modes, which have often been regarded as three distinct properties, of *extension*, *density*, and *impenetrability*. Extension is a term as applicable to space as to matter: "The extension of body," observes Mr. Locke, "being nothing but the cohesion or continuity of solid, separable, moveable parts; and the extension of space the continuity of unsolid, inseparable, and immoveable parts." Hence extension applies to all directions of matter, for its continuity may take place in all directions; but in common language the longest extension of a body is called its length, the next its breadth, and the shortest its thickness.

Density is a property in matter to cohere with a closer degree of approximation between the different particles of which it consists; so that the same body, when in the exercise of this property, occupies a smaller portion of space than before it was called into act. Hence density cannot be a property of space, the parts of which, as I have just observed, are immoveable, and cannot, therefore, either approach or recede.

Impenetrability is the result of density, as density is of extension. It is that property in matter which prevents two bodies from occupying the same place at the same time. They

are all branches of the common property of cohesibility. A wedge of iron, indeed, may force its way through the solid fibres of the trunk of a tree; but it can only do this by separating them from each other: it cannot penetrate the matter of which those fibres consist. In like manner, when a ship is launched, her hulk cannot sink into the water without displacing the exact bulk of water which existed in the space that the hulk below the surface now occupies.

To a cursory survey, however, there are some phænomena that seem to show that certain bodies are penetrable by others. Thus, if a cubic inch of water be mixed with a cubic inch of spirit of wine or sulphuric acid, the bulk of the compound will be something less than two cubic inches. But in this case one of the fluids appears to admit a part of the other fluid into its pores; a fact of which there can be little doubt, since, if no evaporation be allowed to take place, though the bulk of the mixture is somewhat diminished, its weight is precisely equal to what it ought to be. The combination of different metals affords, not unfrequently, similar instances of equal introsusception.

Divisibility is a power in matter directly opposed to its cohesibility. It is that property of a body by which it is capacified for separating into parts, the union or continuity of which constituted its extension.

Divisibility, however, does not destroy cohesion in every instance equally; though the farther

it proceeds the farther it loosens it. We are told by Mr. Boyle, that two grains and a half of silk were, on one occasion, spun into a thread not less than three hundred yards long, which is, notwithstanding, a much shorter length than the spider is capable of spinning his web of the same weight. Muschenbroek mentions an artist of Nuremburg, who drew gold wire so fine that 500 inches of it only weighed one grain; and Dr. Wollaston has obtained platinum wire as fine as $\frac{1}{30000}$th of an inch.* The thickness of tin-foil is about a thousandth part of an inch†; that of gold-leaf is less than a two hundred thousandth part of an inch; and the gilding of lace is still thinner, probably in some cases not more than a millionth part of an inch; and there are living beings, visible to the microscope, of which a million million would not make up the bulk of a common grain of sand. Yet it is highly probable, from what has actually been ascertained of the anatomy of minute and microscopic animals, that many of these are as complicated in their structure as the elephant or the whale.

Gravitation is the common basis upon which all the preceding properties are built, except passivity; the great principle into which all the rest resolve themselves. Gravitation is the

* Wollaston in Phil. Trans. for 1813, p. 114. Thomson's Annals of Philos. No. III. p. 224.

† Davy's Elem. vol. i. p. 379.

attraction by which bodies of all kinds act upon each other, with a force regulated by the aggregate proportion of their respective quantities of matter, and decreasing as the squares of the distances increase. It is a law impressed on matter universally, and hence operates alike on the minutest and on the largest masses; produces what we call weight on earth, or the tendency of heavy bodies to fall towards the earth's centre; and governs the revolutions of the planets. The five principles which regulate its mode of action, and constitute its magnificent code of laws, are thus summed up by M. La Place.*

1. Gravitation takes place between the most minute particles of bodies.

2. It is proportional to their masses.

3. It is inversely as the squares of the distances.

4. It is transmitted instantaneously from one body to another.

5. It acts equally on bodies in a state of rest, and upon those which, moving within its range, seem to be flying off from its power.

To a casual observer there are many substances that seem to fly away from the earth, and consequently to oppose this general law. Thus smoke, when extricated from burning bodies, and vapour, when separated from liquids, ascend into the atmosphere; and a piece of cork, plunged to the bottom of a vessel of water, rises

* Exposition du Systême du Monde.

rapidly to the surface. But, in all these phænomena, the bodies that seem to move upwards merely give way to bodies of a heavier kind, or, in other words, which have a stronger tendency towards the earth. Thus smoke and vapour only ascend, because the surrounding air, which is heavier than these, presses downwards and takes their place; and the cork rises because lighter than the water into which it has been plunged: but empty the vessel, and the cork will remain at the bottom, because heavier than the surrounding air; and let the smoke or the vapour be received into a vacuum, and it will remain as much at the bottom as the cork.

It was first systematically demonstrated by Sir Isaac Newton, that all the motions of all the heavenly bodies depend upon the same power; and the principle thus struck out has of later years been still more extensively and even more accurately applied to a solution of the most complicated phænomena. This principle in astronomy is denominated the centripetal force, and the term is sufficiently precise for all common purposes; since, although, speaking with perfect strictness, the central point of no solid substance is the actual spot in which its attractive power is chiefly lodged, yet it has been abundantly proved by Sir Isaac, that all the matter of a spherical body, or a spherical surface, may, in generally estimating its attractive force on other matter, be considered as collected in the centre of such sphere. And hence, as all the celestial

bodies are nearly spherical, their action on bodies at a distance may be held the same as if the whole of the matter of which they consist were condensed into their respective centres.

To what extent in the heavens the power of gravitation ranges it is impossible to determine; there can be little doubt, however, that it extends from one fixed star to another, although its effects are too inconsiderable to be calculated by man. It may possibly influence the progressive motion of several of the stars, and, as I had occasion to observe in a preceding lecture, is the cause to which Dr. Herschel ascribes the origin of the material universe, which he supposed at one time, though he seems afterwards to have modified his opinion, as we shall notice in our next study, to have issued from an immense central mass of matter, peculiarly volcanic in its structure, and to have been, consequently, thrown forth in different quantities, and at different times, by enormous explosions; each distinct mass, thus forcibly propelled, assuming, from the common law of projectiles, an orbicular path, and endowed with the common property of the parent body, ejecting in like manner minuter masses at different periods of time, which have equally assumed the same orbicular motion, and ultimately become planets to the body from which they have immediately issued, and which constitutes their central sun.

To produce such an effect, however, and in

reality to produce any of the motions which occur to us in the celestial bodies, the PASSIVITY of matter is just as necessary as its gravitation. I have already observed that, owing to its passivity, or VIS INERTIÆ, matter has a tendency to persevere in any given state, whether of motion or of rest, till opposed by some exterior power; and that the path it assumes must necessarily be that of a right line, unless the power it encounters shall bend it into a different direction. A projectile, therefore, as a planet, for example, thrown forth from a volcano, would travel in a right line for ever, and with the exact velocity with which it was thrown forth at first, if there were nothing to impede its progress, or to alter the course at first given to it. But the attraction of the volcanic sphere from which it has been launched does impede it, and equally so from every point of its surface: the consequence of which must necessarily be, that every step it advances over the parent orb it must be equally drawn back or reined in, and hence its rectilinear path must be converted into a curve or parabola, and a tendency be given to it to escape in this line, which may be contemplated as a line of perpetual angles, instead of in a direct course; and as soon as the projectile or planet has acquired the exact point in which the two antagonist powers precisely balance each other — the power of flying off from the centre, communicated to it by the volcanic impulsion, and which is denominated its CENTRIFUGAL

FORCE, and the power of falling forward to the centre, communicated by the attractive influence of the aggregate mass of matter which the parent sphere contains in itself, and which is called its CENTRIPEDAL FORCE—it will have reached its proper orbit; and, through the influence of this constant antagonism of the two properties of passivity and gravitation, of a centrifugal and centripedal force, persevere in the same to the end of time.

Of the immediate cause of gravitation, or the nature of that power which impels different bodies to an union, we are in a very considerable degree of ignorance; or rather, perhaps, may be said to know nothing at all. It is necessary, however, to notice one very singular phænomenon concerning it, and to give a glance at two out of various theories by which gravitation has been attempted to be accounted for.

The phænomenon is, that although, owing to this power, all bodies have a tendency to come into contact, they never come into actual contact; some kind of pore or open space being still left between the corpuscles of bodies that approach the nearest to each other. Thus, a plate of heated iron, solid as it appears to be, and altogether destitute of pores, becomes contracted in every direction by cold. So, too, as I have already observed, equal measures of water and alkohol, or of water and sulphuric acid, have their bulk sensibly diminished. In like manner, Newton has remarked, that when two plates of

glass are within about a ten thousandth part of an inch of each other, using fine metallic plates as a micrometer on this occasion, they support each other's weight as powerfully as if they were in actual contact, and that some additional force is requisite in order to make them approach still nearer. Nor is the force necessary to produce this effect of trivial moment: Professor Robison has calculated it, and has ascertained by experiment that it is equal to a pressure of about a thousand pounds for every square inch of glass. Air is not necessary to this resistance, for it is equally manifest in a vacuum; yet it is a very curious fact, that under water it almost entirely disappears. It is, however, highly probable that the contact is never perfect, otherwise the two plates might be expected to cohere in such a manner as to become an individual mass.

It is hence clear that matter, from some cause or other, is possessed of a REPULSIVE as well as of an ATTRACTIVE force; and that, like the latter, although its law has not been hitherto exactly ascertained, it increases in a regular proportion to its decrease of distance, or, in other words, as bodies approximate each other.

It has hence been said, and this is the common theory of those who regard gravitation as an essential property of matter, that matter is universally endowed with two opposite powers; by the one of which material substances attract each other and induce a perfect union, and by the

other of which they repel each other when they are on the point of union, and prevent a perfect contact. It is admitted, however, on all hands, and is indeed perfectly clear in itself, that the repulsive power is of an almost infinitely less range than the attractive. I have supposed the attractive power, or that of gravitation, to operate from world to world; yet the repulsive power can never be exerted, except "between such particles as are actually, or very nearly, in contact with each other; since it requires no greater pressure, when acting on a given surface, to retain a gallon of air in the space of half a gallon, than to retain a pint in the space of half a pint, which could not possibly be, if the particles exercised a mutual repulsion at all possible distances."*

This idea, however, of double and opposite powers co-existing in the same substance, and in every corpuscle of the same substance, has been uniformly felt difficult of admission by the best and gravest philosophers; and hence Sir Isaac Newton, while allowing the repulsive power of matter, which in truth is far more obvious to our senses in consequence of its very limited range, has felt a strong propensity to question gravity as forming an essential property of matter itself, and to account for it from another source. "To show," says he, "that I do not take gravity for an essential property of bodies, I

* Dr. Young's Lect. vol. i. p. 612.

have added one question concerning its cause, choosing to propose it by way of question, because I am not yet satisfied about it, for want of experiments."* In this question he suggests the existence of an etherial and elastic medium pervading all space; and supports his supposition by strong arguments, and consequently with much apparent confidence, deduced from the mediums, or gasses, as they are now called, of light and heat, and magnetism, respecting all which, from their extreme subtilty, we can only reason concerning their properties. This elastic medium he conceives to be much rarer within the dense bodies of the sun, the stars, the planets, and the comets, than in the more empty celestial spaces between them, and to grow more and more dense as it recedes from the celestial bodies to still greater distances; by which means all of them, in his opinion, are forced towards each other by the excess of an elastic pressure.

It is possible, undoubtedly, to account for the effects of gravitation by an etherial medium thus constituted; provided, as it is also necessary to suppose, that the corpuscles of such a medium are repelled by bodies of common matter with a force decreasing, like other repulsive forces, simply as the distances increase. Its density, under these circumstances, would be every where such as to produce the semblance of an attraction, varying like the attraction of gravitation.

* Optics, pref. to the second edition.

The hypothesis in connexion with the existence of a repulsive force in common matter has a great advantage in point of simplicity, and may perhaps hereafter be capable of proof, though at present it can only be regarded, and was at first only offered, as an hypothesis.

M. La Place, equally dissatisfied as Sir Isaac Newton with the idea of gravitation being an essential property of matter, passes away from the enquiry with suitable modesty, to practical subjects of far higher importance, and which equally grow out of it, in whatever light it is contemplated. "Is this principle," says he, "a primordial law of nature? or is it a general effect of an unknown cause? Here we are arrested by our ignorance of the nature of the essential properties of matter, and deprived of all hope of answering the question in a satisfactory manner. Instead, then, of forming hypotheses on the subject, let us content ourselves with examining more particularly the manner in which philosophers have made use of this most extraordinary power."*

There is, indeed, one very striking objection to Sir Isaac Newton's suggestion, and which it seems very difficult to repel. It is, that though it may account for the attraction of gravitation, as a phænomenon common to matter in general, it by no means accounts for a variety of particular attractions which are found to take

* Exposition du Systême du Monde, lib. iv. ch. xv.

place between particular bodies, or bodies particularly circumstanced; and which, excepting in one or two instances, ought, perhaps, to be contemplated as modifications of gravitation.

Upon these particular attractions, or modes of attraction, including homogeneous attraction, or the attraction of aggregation, heterogeneous attraction, or the attraction of capillary bodies, elective attraction, and those of magnetism and electricity, each of which is replete with phænomena of a most interesting and curious nature, I intended to have touched in the present lecture, but our limited hour is so nearly expired, that we must postpone the consideration of them as a study for our next meeting. Yet it is not possible to close the observations which have now been submitted, without testifying our gratitude to the memory of that transcendant genius whom the providence of the adorable Architect of the universe at length gave to mankind six thousand years after its creation, to unravel its regular confusion, and reduce the apparent intricacy of its laws to that sublime and comprehensive simplicity which is the peerless proof of its divine original.

It has been said, that the discovery of the universal law which binds the pebble to the earth, and the planets to the sun, which connects stars with stars, and operates through infinity, was the result of accident. Nothing can be more untrue, or derogatory to the great discoverer himself. The earliest studies of Newton

were the harbinger of his future fame: his mighty mind, that comprehended every thing, was alive to every thing; the little and the great were equally the subjects of his restless researches: and his attention to the fall of the apple was a mere link in the boundless chain of thought, with which he had already been long labouring to measure the phænomena of the universe.

Grounded, beyond all his contemporaries, in the sure principles of mathematics, it was at the age of twenty-two that he first applied the sterling treasure he had collected to a solution of the system of the world. The descent of heavy bodies, which he perceived nearly the same on the summit of the loftiest mountains and on the lowest surface of the earth, suggested to him the idea that gravity might possibly extend to the moon; and that, combined with some projectile motion, it might be the cause of the moon's elliptic orbit round the earth: a suggestion in which he was instantly confirmed by observing, that all bodies in their fall describe curves of some modification or other. And he further conceived, that if the moon were retained in her orbit by her gravity towards the earth, the planets must also in all probability be retained in their several orbits by their gravity towards the sun.

To verify this sublime conjecture, it was necessary to ascertain two new and elaborate positions: to determine the law of the progres-

sive diminution of gravity, and to develope the cause of the curves or ellipses of falling bodies. Both these desiderata he accomplished by a series of reasonings and calculations equally ingenious in their origin and demonstrative in their result; and ascertained the truth of his principles by applying them, practically and alternately, to the phænomena of the heavens, and to a variety of terrestrial bodies.

The bold and beautiful theorem being at length arrived at, and unequivocally established—a theorem equally applicable to the minutest corpuscles, and the hugest aggregations of matter,—that all the particles of matter attract each other directly as their mass, and inversely as the square of their distance, he at once beheld the cause of those perturbations of motion to which the heavenly bodies are necessarily and so perpetually subject: it became manifest, that the planets and comets, reciprocally acting and acted upon, must deviate a little from the laws of that perfect ellipse which they would precisely follow if they had only to obey the action of the sun: it was manifest, that the satellites of the different planets, exposed to the complicated action of the sun, and of each other, must evince a similar disturbance: that the corpuscles which composed the different heavenly bodies in their formation, perpetually pressing towards one common centre, must necessarily have produced, in every instance, a spherical mass: that their rotatory motion must

at the same time have rendered this spherical figure in some degree imperfect, and have flattened these masses at their poles; and, finally, that the particles of immense beds of water, as the ocean, easily separable as they are from each other, and unequally operated upon by the sun and the moon, must evince such oscillations as the ebbing and flowing of the tides. The origin, progress, and perfection of these splendid conjectures, verifications, and established principles, were communicated in two distinct books, known to every one under the titles of his "Principia" and his "Optics;"—books which, though not actually inspired, fall but little short of inspiration, and have more contributed to exalt the intellect of man, and to display the perfections of the Deity, than any thing upon which inspiration has not placed its direct and awful stamp.

LECTURE V.

ON THE PROPERTIES OF MATTER, ESSENTIAL AND PECULIAR.

(The subject continued.)

We closed our last lecture with remarks on the universal operation of the common principle of gravity over matter in all its visible forms, from the minutest shapes developed by the microscope, to the mightiest suns and constellations in the heavens. But we observed, also, that independently of this universal and essential power of attraction, matter possesses a variety of peculiar attractions dependent upon circumstances of limited influence, and which consequently render such attractions themselves of local extent.

These I will now proceed to notice to you in the following order: — 1st, The attraction of *homogeneous* bodies towards each other, which is denominated, in chemical technology, the attraction of aggregation: 2dly, The attraction of *heterogeneous* bodies towards each other, under particular circumstances, which in its more obvious cases is denominated capillary attraction: 3dly, The attraction of bodies exhibiting

a peculiar degree of affinity to each other, and which is denominated elective attraction: 4thly, The attraction of the electric fluid; and, 5thly, That of the magnetic.

I. The law of physics which has rendered every material substance capable of attracting and being attracted by every other material substance seems at the same time to have produced this power in a much stronger degree between SUBSTANCES OF LIKE NATURES. Thus, drops of water placed upon a plate of dry glass have a tendency to unite, not only when they touch, but when in a state of vicinity to each other; and globules of quicksilver still more so: and it is this kind of attraction which is called the attraction of aggregation. And in both these cases the attraction in question evinces a considerable superiority of force to the general attraction of gravitation; since the particles of the drops or globules ascend from the surface of the glass, except those that form their narrow base, and are drawn towards their proper centres, instead of being drawn towards the centre of the earth.

If, however, the convex shape of the drop of water be destroyed by pressing it over the glass into a thin extended film, the general attraction of gravitation, acting with increased effect upon an increased space, will overpower the individual attraction of aggregation, and the particles of water will be restrained from attempting a spherical figure as before. In the quicksilver, nevertheless, the attraction of aggregation being

much stronger than in the water, it will still continue to prevail; and it is only by a very minute and elaborate division of the particles of this material that we can give to the attraction of gravitation a predominancy.

The same result occurs in the homogeneous particles of oil. And hence, if we divide its particles by shaking a certain portion of it in water, we find, upon giving the mixture rest, that the water will first sink to the bottom, or, which is the same thing, the particles of the oil will rise to the surface; and then that these particles, as soon as they have reached the range of each other's attraction, will unite into one common body.

Now, in all these cases it is obvious that the particles of matter thus obeying the law of homogeneous attraction assume or attempt to assume a spherical figure; and we not unfrequently perceive a similar attempt, even where the breadth of the surface, and the consequent potency of the attraction of gravitation, would hardly induce us to expect that there could be the least effort towards it: as, for example, in a glass brim-full, or somewhat more than brim-full of wine, or any other liquid.

We behold the same figure in the drops of rain as they descend from the clouds; a figure which, in fact, is the sole cause of the vaulted form of the rainbow, as I may possibly take leave to explain more particularly on some future occasion. We behold it in reality throughout

all nature, in every substance whose particles are capable of uniting and separating with ease; and, consequently, of readily obeying the laws of cohesibility and divisibility, as those of liquids; and we should see it equally in solids, but that the particles of these last are incapable of doing readily either the one or the other.

What, then, is the general cause that produces so general an effect? Clearly this: a cause to which I have already in some degree adverted, in speaking of the general attraction of gravitation: that, there being an equal tendency in every particle of homogeneous bodies to press together, they must press equally towards one common centre, and strive to be as little remote from that centre as possible. Such a strife, however, must necessarily produce a globular or spherical form; for it is in such a form only that the extreme particles, or those constituting its surface, and which are prevented from a closer approach by those that lie within, are equally near and equally remote in every direction.

Hence, then, the cause of the globular figure of drops of quicksilver, drops of water, drops of rain, and drops of dew, collected and suspended from the fresh leaves of plants in the balmy air of the morning: and hence one reason, though there is also another that concurs with it, and which I shall explain presently, for the convex shape assumed by a wine-glass of liquid of any kind, on its surface, when brim-full, or somewhat more.

The same reasoning may be applied to account for the spherical figure of the heavenly bodies; each of which, though probably composed of many different or heterogeneous substances in itself, may be fairly contemplated as a homogeneous mass when compared with those by which it is surrounded: and hence, too, we see the necessity for their having at first existed, from some cause or other, in a fluid state; since, otherwise, the different corpuscles which enter into their make could not have assumed that symmetrical arrangement which alone gives sphericity to the total bulk.

We have equal proofs of the same peculiar attraction existing between solid bodies, though the proofs are not so common; since, as I have just observed, the particles of solid bodies have less power of movement, and, consequently, of adaptation to each other, than those of liquids. Thus, two plates of lead, whose opposite surfaces correspond so exactly that every particle of each surface shall have a bearing upon the particle opposed to it, when once united by pressure, assisted by a little friction, cohere so powerfully as to require a very considerable force to separate them. And it may be shown, either by measuring this force, or by suspending the lead in the vacuum of an air-pump, that the pressure of the atmosphere is not materially concerned in producing this effect. A cohesion of this kind is sometimes of practical utility in the arts; little ornaments of laminated silver remaining

attached to iron or steel, with which they have been made to connect themselves by the powerful pressure of a blow, so as to form one mass with it. And it is now a well known fact, and of a most curious nature, that one of the causes by which eight-day clocks go at times irregularly, and monthly clocks, whose weights are much larger and heavier, often amounting to not less than thirty pounds, stop suddenly, proceeds from the attraction which takes place between their leaden weights and the leaden ball of the pendulum, when the weights have descended just so low as to be on a level, and, consequently, very nearly in a state of contact, with the pendulum-ball. And hence the reason why both these kinds of clocks, if the pendulum have not actually stopped, seem gradually, a few days afterwards, to recover their former accuracy; the attraction diminishing as the distance once more increases.* In like manner, Studor remarks that beams of steel become sometimes erroneous by acquiring magnetic polarity.†

It is by the same means that the greater number of rocks seem to be produced that enter into the substance of the earth's solid crust. The lowermost of these, as I shall have occasion to observe in an ensuing lecture, are united by an intimate crystallization, which is the most perfect form of aggregate or homogeneous attraction

* Reid, in Nicholson's Journal, vol. xxxiii. p. 92.

† Gilb. xiii. 124. Young's Nat. Phil. ii. 159.

that can exist between solid bodies, and which must have commenced while such bodies were in a fluid state. Some of the upper kinds or families are united by a particular cement, which is nothing more than a substance possessing a peculiar attraction, or, if I may be allowed the expression, physical partiality to the rudimental corpuscles of which the rock consists; and others by nothing more than the law of aggregation or homogeneous attraction in its simplest state; whence earths unite to earths in consequence of mutual approximation, assisted by their own or a superincumbent pressure, in the same manner as I have just stated that plates of lead or other metals unite to metals.

II. But there are substances that are UNLIKE IN THEIR NATURE, as solids and fluids, for instance, that under particular circumstances are often found to exhibit a mutual attraction; whence this mode of union is called HETEROGENEOUS ATTRACTION, and, from its occurring most palpably between liquids and solid substances possessing small capillary or hair-tubes, CAPILLARY ATTRACTION.

The cause of this attraction is obvious; and it is still more clearly a mere modification of the general attraction of gravitation, than the preceding power of homogeneous attraction. It is the common attractive property of material substance for material substance; the liquid, or that whose particles are easily separable, pressing towards the solid, whose parts are by any action of

their own altogether inseparable. Hence the reason why water or any other liquid hangs about the sides of a wine-glass: hence, partly, the reason why a wine-glass, when somewhat more than brimfull of a liquid, does not overflow; the co-operative reason being, as I have already stated, the homogeneous attraction of the corpuscles of the fluid for each other, which prevents them from separating readily: and hence also the reason why a liquid contained in a narrow-necked and inverted phial does not obey the common attraction of gravitation, and fall to the earth, although the stopper be removed to allow it, till we aid the power of gravitation, or rather loosen the power of the peculiar attraction, by shaking the phial.

In this last case it is manifest that the heterogeneous attraction, or that between the two different substances, is stronger than the common force of gravity. In minute capillary tubes or pores this is still more obvious. Such are the pores of a piece of sponge, when pressed or softened, so as to become more pliable to the action of water or of any other liquid within its reach. For, in this case, the water being minutely divided by the pores of the sponge into very small portions, and still surrounded by the pores in every direction after such division, has its common force of gravitation and its peculiar force of homogeneous attraction equally overpowered; and ascends from the surface of the earth, instead of descending to it, or uniting into a spherical form; and the same kind of

pores, and, consequently, the same kind of power, being continued to the upmost height of the sponge, it will rise to the full extent of its column. The tubes of various imperfect crystals, as those of sugar, for example, are still smaller; and hence the lateral attraction must be still stronger; and any liquid within its reach will rise both higher and more freely, till the sugar at length becomes dissolved, and, consequently, its pores are totally destroyed. The cause of capillary attraction is therefore obvious: and the reasoning and phænomena now submitted may be applied to an explanation of every other species of the same kind that may occur to us.

III. The third particular attraction I have noticed, is that of PECULIAR BODIES FOR PECULIAR BODIES, and which has hence been denominated ELECTIVE OR CHEMICAL ATTRACTION; as the tendencies they have to each other have been denominated AFFINITIES. Thus lime has a strong affinity for carbonic acid, and greedily attracts it from the atmosphere, which hence becomes purified by being deprived of it. But the same substance has a still stronger affinity for sulphuric acid, and hence parts with its carbonic acid, which flies off in the form of gass, in order to unite with the sulphuric whenever it has a possibility of doing so. It is highly probable that this kind of attraction is also nothing more than a peculiar modification of that of gravitation, more select in its range, but more active in its

power. To trace out the various substances that are possessed of this peculiar property, and to measure the degrees of their affinities, is one of the chief branches of chemistry, but of too voluminous a nature to touch farther upon at present.

IV. V. The two remaining kinds of attraction to which I have adverted, those of ELECTRICITY and of MAGNETISM, are still more select, and perhaps still more powerful than even the preceding; but the phænomena to which they give rise cannot, I think, be attributed to any modification of a gravitating etherial medium. We call the medium in both these cases a fluid, but we know little or nothing of the laws by which they are regulated; whether they be different substances, or, according to M. Ampore, the same substance under different modifications, or whether, in reality, they be material substances at all. They are certainly deficient in the most obvious properties of common matter, and may be another substrate of being united to it.

There are also two other substances, or which are generally conceived to be substances, in nature, of a very attenuate texture, which largely contribute to the changes of material bodies. I mean LIGHT and HEAT, of the general nature of which we are still also in a considerable degree of ignorance. Like the powers of magnetism and electricity, we only know them, and can only reason concerning them, by their effects. These effects, indeed, are of a most curious and

interesting character, but spread too widely to be followed up in the course of the present lecture, though we may endeavour to pursue them, and, as far as we are able, to develope them, hereafter.

All these four powers or essences, for we know not which to call them, concur in exhibiting none of the common properties of matter; their respective particles repel each other at least as powerfully as they attract, and in the cases of light and heat repel alone, and without attracting. They may, possibly, be ponderable; but if so, we have no instruments fine enough to detect their relative weights; and we are hence incapable of determining, as I took leave to observe on a former occasion, whether they be matter at all, whether mere properties of matter, or whether modifications of some etherialized and incorporeal substrate, combining itself with the material mass, and exciting many of its most extraordinary phænomena. It is at present, however, very much the habit to generalise them into one common origin; and to conceive the whole as modified results of matter, or of the gravitating property of matter. Thus, the attractive powers of chemical affinity and of electricity are identified in the following passage of Sir Humphry Davy's valuable "Elements of Chemical Philosophy:"—"Electrical effects are exhibited by the same bodies when acting *as masses*, which produce chemical phænomena when acting by their *particles*; it is not improbable, therefore, that

the primary cause of both may be the same."* And in like manner, in an adjoining passage, he suggests that all the various properties or essences that have thus far passed in survey before us may be nothing more than the general attractive power of matter, though he admits that at present we are incompetent to determine upon the subject. "With regard to the great speculative questions, whether the electrical phænomena depend upon one fluid *in excess* in the bodies positively electrified, and *in deficiency* in the bodies negatively electrified, or upon two different fluids capable by their combination of producing heat and light, or whether they may be *particular exertions of the general attractive power of matter*, it is perhaps impossible to decide, in the present imperfect state of our knowledge."†

And hence, heat, in the view of Sir Humphry Davy, Count Rumford, and various other justly celebrated chemists and philosophers of the present day, coincidently with the doctrine of the Peripatetic school, is a mere property of matter, and not a substance sui generis, as was contended for by the Epicureans, in opposition to the disciples of Aristotle, and is contended for by the disciples of Boerhaave, Black, Crawford, and most of the chemists of our own times. The cause of heat, among those who deny it a substantive existence, consists in a vibrating motion of the constituent particles of the heated body,

* Elem. p. 164, 165. † Id. p. 176.

too rapid to be traced by the eye. And as it is known to every one that bodies in general, as they become heated, occupy a larger space, and have their particles more widely repelled and separated from each other than in a colder temperature, it has of late become a favourite doctrine that the repulsive power, which in our last lecture we noticed to exist throughout matter, depends altogether upon the property of heat, in consequence of which Sir Humphry Davy uses heat and calorific repulsion as synonymous terms, and hence regards heat and gravitation, or general attraction, as antagonist powers.

There is much plausible reasoning to be urged in favour of this hypothesis. It will as readily account for many, perhaps most, of the phenomena which accompany bodies in their change from one temperature to another, as the position of the substantive form of heat, and has some advantage in point of simplicity; but it is opposed by a variety of facts of so stubborn and intractable a nature, that no efforts of ingenuity have hitherto been capable of bending them into the service of the new doctrine. I observed, for instance, in our last lecture, that when two plates of glass are within a ten thousandth part of an inch of each other, they cannot be made to approach nearer without a strong additional pressure. I observed, farther, that Professor Robison has calculated the extent of this pressure from actual experiment, and finds it amount to not less than a thousand pounds weight for

every square inch of the glass. Now this resistance or repulsive power between the two plates of glass takes place equally under an air-pump and in the fullest exposure to the air of the atmosphere, but it appears to cease under water. By what cause the repulsion is excited in the two former instances, or disappears in the latter, we know not; but it does not seem possible for any ingenuity of argument to connect this repulsive power with heat, whether regarded as a substance or a mere property.

"Heat, again, which undoubtedly makes the particles of iron repel each other, so that given weights of them occupy a larger space—makes the particles of a ball of clay, on the contrary, attract each other into a closer approximation, and very considerably to lessen its dimensions; and it was on account of this peculiar property that Mr. Wedgewood selected this last material for the purpose of forming his celebrated pyrometer, or instrument for measuring intense heats, the increase of the heat being indicated by the decrease of the mass of clay.

So water, at about 42° of Fahrenheit, which forms its medium of density, begins to expand upon exposure to heat, and continues to expand in proportion as additional heat is applied; but below 42° it begins to expand also, upon exposure to cold, and continues to expand in the very same ratio upon the application of additional cold, till at 32° it freezes and becomes fixt. This curious phenomenon has never been

accounted for. If calorific repulsion produce the expansion above 42°, what is it that produces the same effect below? We can, perhaps, explain the cause of the expansion during the act of freezing, from the peculiar shape of the crystals which the water assumes in the act of consolidating; but this explanation will in no respect apply to the expansion of the water when it reaches the freezing point. In this curious and unillustrated fact cold appears to be as much entitled to the character of a repulsive power as heat.

For these and numerous other reasons, therefore, heat is even at the present moment usually regarded, not as a mere quality of body produced by internal vibration, and forming an antagonist power to the attraction of cohesion, but as a distinct and independent substance. The sources of heat are various, though by far the principal reservoir throughout the whole solar system is the sun himself, which Dr. Herschel believes to be perpetually secreting the matter of heat from those dark and discoloured parts on its surface which we call spots, by many astronomers regarded as volcanoes, and many of which are larger than, and some of them five or six times as large as, the diameter of the earth! This material Dr. Herschel supposes to be first thrown off in the form of an atmosphere, and afterwards this atmosphere to be diffused in every direction through the whole range of the solar empire: and, in the Philosophical Transactions for 1801,

he has endeavoured to show that the variation in the heat of different years is owing to the more or less copious supply of fuel which such spots communicate.

This opinion I at present merely glance at; as it is my intention on a future occasion to examine its validity, as well as to trace out the other sources from which heat is derived, and to take a survey of the laws by which it is regulated. It will form a progressive part of that investigation to follow up the general nature of light; to try the question whether it be a substance or a property; and if a substance, whether distinct from or a mere modification of heat. I shall at present only observe, that, in one of the latest opinions of the philosopher to whom I have just adverted, it is not only a substance, but the source of all visible substances, and the basis of all worlds.

Dr. Herschel has recently taken great pains to prove, but with no small degree of repugnancy to a former hypothesis of his, that the luminous fluid which so often appears in the heavens on a bright night, and shoots streaks athwart them, is diffused light, existing independently of suns or stars, though perhaps originally thrown forth from them; another kind of etherial matter being sometimes united with that of light, and hence rendering it at times capable of opacity. In this diffused state he calls every distinct mass a nebulosity; he conceives all its particles to be subject to the common laws of gravitation, or

the centripetal force; and that certain circumstances, unknown to us, may have occasionally produced a nearer approximation between some particles than between others; whence the diffused nebulosity is, in such part, converted into a denser nucleus, which, by its comparative preponderancy, must lay a foundation for a rotatory motion, and attract and determine the circumjacent matter still more closely to itself, and consequently diminish the extent of the nebulous range.

The nuclei thus arising may sometimes be double or triple, or still more complicated; and whenever this occurs, the nebulosity will be broken into different nebulæ, or smaller nebulous clouds; and if some of them be much minuter than others, the minuter may at length attend upon the larger, as satellites upon a planet: and Dr. Herschel gives instances of all these phænomena actually completed, or in a train of completion, in different parts of the visible heavens.

Such he submits as his latest opinion of the general construction of the heavens; believing stars, planets, and comets to have originated, and to be still originating, from such a source; the nebulous matter contained in a cubical space seen under an angle of ten degrees demanding a condensation of two trillion and two hundred and eight thousand billion times before it can be so concentrated as to constitute a globe of the diameter and density of our sun.

Some of these masses of light are indistinct and barely visible even by Dr. Herschel's forty feet telescope; and he hence calculates, that if a mass thus traced out contain a cluster of five thousand stars, they must be eleven millions of millions of millions of miles off. M. Huygens entertained an analogous idea; and conceived that there are stars so immensely remote that their light, although travelling at the rate of eleven millions of miles in a minute, and having thus continued to travel from the formation of the earth, or for nearly six thousand years, has not yet reached us.

But this sublime conception is of much earlier origin; and it is due to the magnificence of the Epicurean scheme to state that it is to be found completely developed amongst its principles. Lucretius has beautifully alluded to it in lines of which I must beg your acceptance of the following feeble translation, the only difference being, that lightning or the electric fluid, is here employed instead of light, at least by Havercamp; for Vossius, in the Leyden edition, gives us *light* for *lightning*, reading *lumina* instead of *fulmina*.

The poet is speaking of the immensity of space:—

The vast whole
What fancied scene can bound? O'er its broad realm,
Immeasur'd, and immeasurably spread,
From age to age resplendent lightnings urge,
In vain, their flight perpetual; distant, still,

And ever distant from the verge of things.
So vast the space or opening space that swells,
Through every part so infinite alike.*

From this immense range of nebulous light Dr. Herschel derives comets as well as stars and planets, believing them, indeed, to be the rudiments of the two latter; and he has especially noticed, as originating from this source, the well remembered comet that so brilliantly, and for so long a period of time, visited our horizon during the close of the year 1811; which he conceives will be converted into a stellar or planetary orb as soon as its luminous matter, and especially that of its enormous tail, shall be sufficiently concentrated for this purpose. This tail he calculated, when at its greatest apparent stretch in October of the same year, at something more than a hundred millions of miles long, and nearly fifteen millions broad, though its bright or solid nucleus or planetary body was not supposed to measure more than four hundred and twenty-eight miles. Its perihelion path, or nearest approach to the sun, is stated at a distance of

* Omne quidem vero nihil est quod finiat extra.
Est igitur natura loci, spatiumque profundi,
Quod neque clara suo percurrere fulmina cursu
Perpetuo possint ævi labentia tractu;
Nec prorsum facere, ut restet minus ire, meando
Usque adeo passim patet ingens copia rebus,
Finibus exemptis, in cunctas undique parteis.†

† De Rer. Nat. i. 1000

ninety-seven millions of miles, its distance from the earth at ninety-three millions. The comet of 1807 approached the earth within sixty-one millions of miles, or about a third nearer the earth, and that of 1680 within a sixth of its diameter, or as near as 147,000 miles, its tail being of a like length.

There is one comet, however, that we seem to be somewhat better acquainted with than with this that paid us so near a visit, or indeed than with any other, from its having approached us visibly for four times in succession, if not oftener. It was towards the beginning of last century that Mr. Halley was struck with the remark, that the general elements and character of the comets observed in 1531, 1607, and 1682, were nearly the same; whence he concluded that the whole formed but one identical body, that took about seventy-six years to complete its eccentric orbit; and hence, although in consequence of this eccentricity, and its travelling amidst a range of heavenly bodies that are altogether invisible to us, and whose influence seems to bid defiance to calculation, it is difficult to form an estimate of its progress, he ventured to suggest, that it would appear again, making due allowances for these incidents, towards the close of 1758, or the commencement of 1759: and he had the high satisfaction of seeing his prediction verified; the comet passing its perihelion March 12th, 1759, within the limits of the errors of which he thought his results

susceptible. It is apparently this comet, which at this last period only excited the curiosity of astronomers and mathematicians, that in 1456, or four revolutions earlier, towards the close of what are called the dark ages, spread such consternation over all Europe, already, indeed, terrified by the rapid successes of the Turkish arms, that Pope Callixtus was induced to compose a prayer for the whole western church, in which both the Turks and the comet were included in one sweeping anathema.

Admitting the truth of Dr. Herschel's hypothesis, as we are now contemplating it, it is possible that some of the lately discovered planets, which are now attendant upon the sun, were formerly comets, whose orbits have for ages been growing progressively more regular, as well as their constitutional rudiments more dense; and such, indeed, is the opinion of M. Voight, and of various other philosophers on the continent.

The object of the present and the preceding lecture has been to submit a sketch of the most obvious properties belonging to MATTER, so as to enable you to obtain a bird's-eye-view of the general phænomena it is capable of assuming, and the general changes it is necessarily sustaining. From the qualities I have placed before you, of passivity, cohesibility, divisibility, and attractions of various kinds, must necessarily result, according to the intensity with which they are called into action, the phænomena of liquidity, viscidity,

toughness, elasticity, symmetry of arrangement, solidity, strength, and resilience. But the powers which thus perpetually build up the inorganic world, and to this our survey has been entirely confined, perpetually also destroy it: for the whole, as I have had occasion to observe, is a continued circle of action; a circle most wise, most harmonious, most benevolent: and hence, as one compound substance decays, another springs up in its place, and can only spring up in consequence of such decay.

There is, however, another lesson, if I mistake not, which we may readily learn from these lectures, however imperfectly delivered, and which is altogether of a moral character: I mean that of humility, in regard to our own opinions and attainments; and of complacency, in regard to those of others. After a revolution of six thousand years, during the whole of which period of time the restless ingenuity of man has been incessantly hunting in pursuit of knowledge, what is there in physical philosophy that is thoroughly and perfectly known even at the present moment? and of the little that is thus known, what is there which has been acquired without the clash of controversy, and the warfare of opposing speculations? Truth, indeed, — for ever praised be the great Source of Truth, for so eternal and immutable a decree — has at all times issued, and at all times will issue, from the conflict; but while we behold philosophers of the highest reputation,

philosophers equally balanced in the endowment of native genius, proved by the great teacher Time to have been alternately mistaken upon points to which they had honestly directed the whole acumen of their intellect, how absurd, how contemptible is the fond confidence of common life! Yet what indeed, when fairly estimated by the survey that has now been briefly taken of the sensible universe, — what is the aggregate opinion, or the aggregate importance of the whole human race! We call ourselves lords of the visible creation: nor ought we at any time, with affected abjection, to degrade or despise the high gift of a rational and immortal existence. — Yet, what is the visible creation? by whom peopled? and where are its entrances and outgoings? Turn wherever we will we are equally confounded and overpowered: the little and the great are alike beyond our comprehension. If we take the microscope it unfolds to us, as I observed in our last lecture, living beings, probably endowed with as complex and perfect a structure as the whale or the elephant, so minute that a million of millions of them do not occupy a bulk larger than a common grain of sand. If we exchange the microscope for the telescope, we behold man himself reduced to a comparative scale of almost infinitely smaller dimension, fixed to a minute planet that is scarcely perceptible throughout the vast extent of the solar system; while this system itself forms but

an insensible point in the multitudinous marshallings of groups of worlds upon groups of worlds, above, below, and on every side of us, that spread through all the immensity of space, and in sublime, though silent harmony declare the glory of God, and shew forth his handywork.

LECTURE VI.

ON GEOLOGY.

There are some subjects on which the philosopher is obliged to exercise nearly as much imagination as the poet; for it is the only faculty by which he can expatiate upon them. Such is a great part of the magnificent study upon which we have touched in our preceding lectures. — Space, immensity, infinity, pure incorporeal intelligence, matter created out of nothing, innumerable systems of worlds, and innumerable orders of beings; — where is the mind strong enough to grapple with such ideas as these? They at once entice and overwhelm us. Reason copes with them till she is exhausted, and then gives us over to conjecture. Hence, as we have already seen, invention at times takes the place of induction, and the man of wisdom has his dream as well as the man of fancy.

Let us descend from such magnificent flights: let us quit the possible for the actual; and equally incapable of following up the fugitive material of which the visible universe consists, into its elementary principles and collective mass, let us examine it as far as we are able,

in the general laws, structure, and phænomena it exhibits in the solid substance of the globe on which we tread.

It is this enquiry that constitutes the science of GEOLOGY, a brief outline of which is intended as a study for the present lecture; — a science than which few are of more importance, but which is only at present in its infancy, and of course almost entirely indebted for its existence to the unwearied assiduity and discoveries of modern times.

The direct object of geology is, to unfold the solid substance of the earth — to discover by what causes its several parts have been either arranged or disorganised — and from what operations have originated the general stratification of its materials, the inequalities of its surface, and the vast variety of bodies that enter into its make.

In pursuing this investigation, many difficulties occur to us. The bare surface, or mere crust of the earth's structure, is the whole we are capable of boring into, or of acquiring a knowledge of, even by the deepest clefts of volcanoes, or the deepest bottoms of different seas. It is not often, however, that we have the power of examining either seas or volcanoes so low as to their bottom. The inhabitable part of the globe bears but a small proportion to the uninhabitable, and the civilized an almost infinitely smaller proportion still. Hence our experience must be extremely limited; a thou-

sand facts may be readily conceived to be unfolded that we are incapable of accounting for; and, at the same time, a variety of contradictory hypotheses to be formed with a view of accounting for them.

So far as the superficies of the earth has been laid open to us by ravines, rivers, mines, earthquakes, and other causes, we find it composed of a multitude of stony masses, sometimes simple, or consisting of a single mineral substance, as lime-stone, serpentine, or quartz; but more frequently compound, or constructed of two or more simple materials, variously intermixed and united; as granite, which is a composition of quartz, felspar and mica; and sienite, which is a composition of felspar and hornblend. These stony masses or rocks are numerous, and they appear to be laid one over the other, so that a rock of one kind of stone is covered by a rock of another kind, and this second by a third kind, and so on, in many instances, for a very considerable number of times in succession. In this superposition of rocks it is easily observable that their situation is not arbitrary. Every stratum occupies a determinate place; so that they follow each other in regular order from the deepest part of the earth's crust, which has been examined, to the very surface. Thus there are two things respecting rocks which claim our peculiar attention — their composition and their relative situation. And independently of the rocks thus considered as constituting almost

the whole of the earth's crust, there are other masses of fossil materials that must be likewise minutely studied; which traverse rocks in a different direction, and are known by the name of veins; as if the rocks had been split asunder in different places from top to bottom, and the chasms had been afterwards filled up with the matter which constitutes the vein. And hence the VEINS which intersect rocks are as much entitled to our attention as the STRUCTURE and SITUATION of the rocks themselves.

Rocks, as to their STRUCTURE, may be contemplated under two divisions, *simple* and *compound*.

The simple division is, however, rather a speculative than a practical contemplation. It is possible that rocks; and of immense magnitude, may exist in parts of the globe we are not acquainted with, that are perfectly simple and unmixed in their structure; but it is seldom, perhaps never, that they have been actually found in such a state, at least to any considerable extent.

It is only under a compound form, therefore, or as composed of more than one mineral substance, that rocks are to be contemplated in our present survey of the subject; and in this form we meet with them of two kinds: CEMENTED, or composed of grains, or nodules, agglutinated by a cement, as sandstone and breccia or pudding-stone; and AGGREGATED, or composed of parts connected without a cement, as granite

and gneiss. The component parts of the cemented rocks are often very multifarious; those of granite and gneiss much less so, consisting chiefly of felspar, mica, and quartz, with garnets, shorl, or hornblend occasionally intermixed with the mass. The granite that forms the flag-stones of Westminster Bridge are supposed to have been brought from Dartmoor; and, like the rest of the Dartmoor granite, is remarkable for the length of its crystals of felspar, which in some instances are not less than four inches.

The aggregate rocks; like the cemented, are sometimes found of an indeterminate, but more generally of a determinate or regular form; and it is the office of that branch of mineralogy to which M. Werner has given the name of *oryctognosy*, to distinguish and describe them by those peculiarities. This is a branch into which I cannot plunge, for it would lead us from that general view of the science to which our present course of study is directed, into a detailed analysis. Those who are desirous of pursuing it in this line of developement may consult with great advantage Professor Jameson's System of Mineralogy, or M. Brogniart's "Traité Elémentaire," or M. Cuvier's Essay on the Theory of the Earth, prefixed to his Fossil Remains. I can only observe, at present, that the total number of rocky masses, or different kinds of rocks, whether simple or compound, which have been hitherto observed, amount to about sixty; of

which the principal seem to be the eight following: granite, gneiss, hornblend, limestone, wacke, basalt, quartz, and clay.

Let us next pass on, then, to consider their RELATIVE SITUATION. Of the different rocks thus glanced at, and placed over each other, the whole crust of the earth is composed, to the greatest depth that the industry of man has been able to penetrate; and I have already observed, that, with respect to each other, they occupy a determinate situation, which holds invariably in every part of the globe. Thus, limestone, excepting under particular circumstances hereafter to be explained, is no where found under granite, but always above it. This general view of the subject may indeed induce a supposition that every separate layer which constitutes a part of the earth's surface is extended round the entire globe, and wrapped about the central nucleus, like the coats of an onion; the kind of rock that is always lowest, or nearest the centre, uniformly supporting a second kind, and this second kind a third, and so on. Now, though the different kinds or layers of rocks do not in reality extend round the earth in this uninterrupted manner — though, partly from the inequality of the nucleus on which they rest, partly from their own inequality of thickness in different places, and partly from other causes, the continuity is often interrupted — yet still we trace enough of it to convince us that the rocks which constitute the crust of the earth, when contemplated upon

a large scale, are every where the same, and that they invariably occupy a like situation with respect to each other.

The labours of Mr. Kirwan and M. de Saussure gave the earliest hints upon this subject; and the geological theories of Professor Werner of Freyburg, and of M. de Cuvier of Paris, are entirely founded on the same. These theories, though derived in some measure from different sources of mineralogical study, coincide not merely in their general outline, but in all their more prominent parts, and only differ in their mode of accounting for the more limited or local deposites.

M. Werner, " from whom alone, to adopt the language of M. de Cuvier, we can date the commencement of real geology," so far as respects the mineral natures of the strata, divided in his first view of the subject, all the various rocks that enter into the solid crust of the earth into FIVE classes.

Of these the FIRST CLASS consists of those rocks which, if we were to suppose each layer to be extended over the whole earth, would lie lowest, or nearest the centre, and be covered by all the rest; it comprises seven distinct sets, as granite, gneiss, mica-slate, clay-slate, a peculiar kind of porphyry, sienite, and a peculiar kind of serpentine. Of these granite lies the undermost; and sienite the uppermost; and in the midst of several of them we meet with beds of not less than eight other kinds of rock, as

though dropped into them by accident — as topaz, another kind of porphyry, serpentine, limestone, flint-slate, and trap, quartz and gypsum; which are hence called subordinate rocks of this class, and which extend the whole number of sets belonging to it to fifteen.

These are supposed to have been earliest produced, and when the earth first emerged from a state of chaos to a state of order; and are hence denominated PRIMITIVE FORMATIONS. They are distinguished by the following character. Not a single relic of either animal or vegetable petrifaction is to be found in any of them. The lowermost or older contain no carbonaceous matter; which is discoverable but very sparingly in the superior or newer. They are all chemical combinations, and generally crystallized; the crystallized appearance being most perfect in the oldest, and gradually becoming less perfect in the newer formations. I have already observed that the whole of this scale of formations does not regularly coat the nucleus of the earth; so little so, indeed, that sometimes even the granite itself, the lowermost rock of all, is left bare, and not pressed down or coated by a deposite of any other kind of rock: and so of the rest. Where-ever this deficiency takes place, the rock thus left at liberty rises uniformly higher than it is found to do where pressed upon, and invested with its common coatings. But every rock does not, under such circumstances, rise equally high, or with an equal degree of freedom; for granite

rises highest of all; and hence we frequently find it composing the tops of our loftiest chains of mountains, as well as the basis of the earth's solid crust. It forms the great body of the Swiss mountains and the Alps, though gneiss is here also found in great abundance.

The level of gneiss, when left at equal liberty, is a little lower than that of granite. It constitutes the vast mass of the Carpathian mountains that divide Transylvania and Hungary from Poland.

The level of mica-slate is lower than that of gneiss, and the level of clay-slate lowest of all. So that there is a regular sinking of these respective levels from granite to clay-slate: while the newer porphyry and sienite are often laid over their summits, as though these two formations had been deposited long after the production of the others; an idea which is still further strengthened by our meeting occasionally with a bed of breccia, or pudding-stone, composed of fragments of the older or lower rocks, capping the gneiss, granite, or other formation before the porphyry or sienite has been deposited.

The SECOND CLASS of rocks, or that which, when the number of coatings is complete, lies immediately over the preceding, consists of grey-wacke slate, and a peculiar kind of limestone, greenstone, and amygdaloid; together with subordinate masses of the proper primitive formations, sienite, porphyry, and granite: as though some portions of these had become crystallized after

the rest, along with the next layers in succession, or had been separated from the parent rocks by some early commotion. Grey-wacke, which is a concrete term, denoting a conglomerate rock of a peculiar kind having a basis of clay-slate, and being studded or otherwise intersected with portions of quartz, felspar, and scales of mica, may be exemplified by what in Cornwall is called *killas*, a far more euphonous word; and hence grey-wacke and grey-wacke slate may be distinguished by the terms *amorphose* and *schistose* killas. The Cornish killas lies directly over the granite of that county, which possesses the character ascribed by Werner to granite of the highest antiquity.*

These formations, for the most part, irregularly alternate with each other, instead of preserving one regular and successive order, as the different sets of the primitive formations do; excepting that the limestone appears usually undermost, and placed, as the basis of the rest, upon the sienite or uppermost of the first class. It is in this second class of formations that petrifactions first make their appearance; and it deserves particular attention that they are uniformly confined, both in the animal and vegetable kingdoms, to those of the lowest links in the scale of organization; and even among

* See Allan's remarks on the transition-rocks of Werner, in Thomson's Annals of Philos. vol. iii. p. 23. Compare with Jameson's definition of the same. Id. Feb. 1817, p. 17.

these to species which are at present altogether unknown, and which appear therefore to be totally extinct. Thus the animal petrifactions consist entirely of ammonites, mytilites, unknown corals, and other zoophytic worms; and the vegetable petrifactions of reeds, ferns, and other palm-like plants, mosses, and other cryptogamic productions, which occupy the lowest part in the scale of vegetable life, as zoophytic worms do among animals. It is here, also, that carbonaceous matter, which is chiefly of vegetable origin, first makes its appearance in any considerable quantity.

To this class of rocks, therefore, M. Werner has given the name of TRANSITION FORMATIONS; as believing them to have been produced while the earth was in a state of transition from inorganic matter to organic life,—from an uninhabited to an inhabited condition. The date of their formation, however, is proved, even from their natural appearance, to have been very remote; since, as already observed, the whole of the petrifactions which they contain consist of plants and animals, not only of the very lowest species, but which now seem to be altogether extinct.

The THIRD CLASS of rocks is denominated FLOETZ, that is, FLAT OR HORIZONTAL, FORMATIONS, in consequence of their usually appearing in beds much more nearly horizontal than the preceding. They lie immediately over the

transition-class, and consist of the twelve following distinct sets of rock, each of which is generally found in a particular situation: sandstone of different kinds, and differently arranged, three sets; limestone, three sets; gypsum, two sets; calamine; chalk; coal; trap. The trap usually covers the whole of this class, as the newer porphyry and sienite cover the primitive formations: the relative position of the rest is more variable. The floetz or horizontal class is characterized by its containing an abundance of petrifactions in every one of its sets, and these of known animal and vegetable kinds; though still, of those that occupy the lower parts of the scale, as shells, fishes, the fishes much mutilated, a few tortoises, ferns, pines, and reeds; indicating that they were formed at a period in which organized beings of this character abounded, but in which those of other characters did not exist, or but rarely.

The FOURTH CLASS of formations, under the Wernerian system, is denominated ALLUVIAL, and constitutes the great mass of the actual surface of the earth's solid crust. They have been evidently produced by the gradual action of rain, river-water, air, and the elastic gasses, upon the other classes, and may, comparatively, be considered as very recent formations, or rather as deposites, whose formations are still proceeding. They may be divided into two kinds; those deposited in the vallies of moun-

tainous districts, or those elevated plains which often occur in mountains; and those deposited upon flat land.

The first kind consists of sand, gravel, and similar materials, which constituted part of the neighbouring mountains in their original state, and which remain, notwithstanding that these less durable parts have been thus washed or blown away. They sometimes contain ores, which also existed in the neighbouring mountains, and have been carried down by the agency of rain, air, or the elastic gasses. The ores principally discovered in such situations are those of gold and tin; and these soils are often washed in order to separate them. Beds of loam are also occasionally met with on the plains of mountains, formed of the decomposed elements of animal and vegetable bodies that once occupied their sides.

The second kind of alluvial deposites, or that which occupies the flat land, consists of loam, clay, sand, marl, calcsinter, and calctuff, or stalactitic tufa, the basis of our common petrifactions; and which is found very largely in Sweden, Germany, and Italy, clothing with a calcareous coat the smaller branches of trees, leaves, prickles, moss, and other minute plants; eggs, birds, and birds-nests; preserving them from decay, by defending them from the action of the air. The clay and sand sometimes contain petrified wood; and in many parts are found

the skeletons of quadrupeds, even of the largest magnitudes, as we shall have occasion to observe hereafter.* Here, also, occur earths and brown coal (in which is often traced mineral amber), wood-coal, bituminous wood, and bog iron ore.

The LAST, OF UPPERMOST, of THE FIVE CLASSES of rocks of the Wernerian system, is denominated VOLCANIC FORMATIONS; and consists of two distinct sets, false and true.

The false comprise mineral substances which have experienced a change from the combustion of beds of coal situated in the neighbourhood: the chief minerals which are thus altered are porcelain, jasper, earth, slag, burnt-clay, columnar clay iron-stone, and, perhaps, polishing slate.

The real volcanic minerals are those which have been thrown out of the crater of a volcano, and consist of three kinds: first, those which, having been discharged frequently, have formed the crater itself of the mountain: secondly, those which have rolled down in a stream, and are known by the name of lavas: and, thirdly, the residual matter contained in the water which is often ejected, composed of ashes and other light substances, and which, when rendered solid by evaporation, is denominated volcanic tuff or tufa.

* See series ii., lect. ii. On zoological systems, and the distinctive characters of animals.

I have observed, that these different classes of mineral formations are often traversed in various directions by other mineral substances which are called VEINS, as if the rocks they compose had split asunder in different places from top to bottom, and the chasms had been afterwards filled up from other sources. These transverse lines or veins are worthy of notice in regard to their *shape* and the *substances* with which they are filled.

With respect to their *shape*, they appear to be almost always widest above, and gradually to diminish as they deepen, till at last they terminate in a point; exactly as if they had been originally fissures in the rock. Occasionally, indeed, they are observed to widen and contract alternately in different parts of their course, but this is by no means a common appearance.

Sometimes they are partially or altogether empty; and in this case they are real fissures, and are so denominated; but generally they are filled with matter more or less simple, and more or less different from the rock through which they pass. All the formations I have already noticed as existing in the shape of rocks have also been found in the shape of veins: whence we have veins of granite, porphyry, limestone, basalt, wacke, green-stone, quartz, clay, felspar, pit-coal, common salt, and metals of every kind. When the veins are compound, or consist of a variety of substances, these substances are almost

always disposed in regular layers; one species of mineral constituting a central line or cylinder, and this being encrusted with a second mineral, and the second with a third, and in the same manner to the utmost sides of the veins. These layers are occasionally very numerous; that of the vein Georgius at Freyburg consists of not less than nine, and there is another in the same district, which, according to M. Werner, extends to thirteen. It is not uncommon to find veins crossing each other in the same rock; and when this occurs, one of the veins may be traced passing through the other without any interruption, and completely cutting it in two, the cut vein always separating and vanishing at the point of intersection.

Nothing appears more obvious than that these veins must have been originally fissures produced by some unknown violence in the rocks in which they occur; and it is highly probable, as conjectured by M. Werner, that the mineral materials which constitute them have been deposited slowly from above during the formation of the different classes or sets of rock of which the different layers consist, while the rocks in which they occur were covered with water. Upon this theory veins are of course newer than the rocks in which they are met with, and which must have split to have produced them: and where two veins cross each other, that is obviously the newest that traverses the adjoining without inter-

ruption, as the fissures constituting the second vein must have been formed after the first was filled up.

The FIVE classes of rock formations we have thus far considered are those which entered into Professor Werner's system, as it first made its appearance. They are supposed to exist over the globe generally, and to be independent of chorographic or typographic changes, and have hence been still further denominated UNIVERSAL FORMATIONS.

M. Werner has since, however, been induced to add to these a SIXTH class, consisting of what he has called PARTIAL OR LOCAL FORMATIONS: comprising those which are so often found in vast hollows or basins of particular countries; the materials of which are, in many instances, strangely intermixed, and have probably been carried down into such basins by circumscribed deluges, produced by an exundation of rivers or seas, occasionally alternating with each other, or by other partial disruptions. We have here, therefore, reason to expect,—what in fact is perpetually met with,—a motley combination of whatever substances may have existed in the course of such seas or rivers or rifted soils, with masses or fragments of most of the UNIVERSAL FORMATIONS, alternate beds of marine and fresh-water alluvions, and, consequently, animal and vegetable remains of all kinds.

The composite rocks that fill up the great basin around Paris, in which the skeletons of so

many unknown animals, even quadrupeds of the hugest size, elephants, hippopotami, tapirs, mammoths, and other pachydermatous, or thick-skinned monsters, have been discovered, are of this LOCAL FORMATION. The celebrated quarries of Æningen, on the Rhine, are of a like kind; and these, having been erroneously regarded of the same antiquity as Werner's UNIVERSAL FORMATIONS, have been appealed to by various writers as affording proofs of the falsity of his theory. *

We have other instances of this *local* formation in many parts of our own country, and particularly near the banks of the Thames. Mr. Trimmer has given an interesting account of the substrate of two fields in the vicinity of Brentford, that are loaded with the organic remains of the larger kinds of quadrupeds; as bones of elephants, approaching to both the Asiatic and the African species; horns of deer, apparently as enormous as those dug up in Ireland; bones of the bos genus; and teeth and bones of the hippopotamus; the last very abundant, and intermixed with fresh-water shells †, and other fresh-water relics.

Occasionally, however, marine remains are found intermingled with such animal fossils, and composing their beds instead of those of fresh-

* For an admirable defence of this part of the theory, see Mr. Jameson's essay "On Formations," inserted in the Annals of Philos. no. iii. p. 191.

† Phil. Trans. for 1813, p. 135. See also Mr. Webster's valuable essay on the same subject, in vol. ii. of the Transactions of the Geological Society.

water; and not unfrequently layers of the one kind, as in the basin of Paris, are irregularly surmounted by layers of the other. But no human skeletons are discovered in the midst of any of these rocks, although the bones of man are as capable of preservation as those of any other animal: the only known instance of this sort being that imported into our own country from Guadaloupe by Sir Alexander Cochrane, and which is now exhibited in the British Museum, imbedded in a block of calcareous stone; a very accurate description of which has been published in the Philosophical Transactions by Mr. König.

It is hence obvious, that the catastrophes which involved these enormous quadrupeds in destruction must have occurred at a period when mankind had no existence in the regions which were thus overwhelmed; and in some places overwhelmed alternately by disruptions and inundations of sea and of fresh water. And it is equally obvious, that as the fossil bones are not rolled or violently distorted, or deprived of their natural contour, such remains have not been brought to their present beds from a distance; but that the deluge must have been sudden, and overtaken them in their natural resorts; and hence may, in many cases, have swept away all the individuals of a species in a common calamity.

There is, however, a great difficulty with some naturalists in conceiving that such animals

as the elephant, the tapir, the rhinoceros, the hippopotamus, the mammoth, or mastodon, animals now only found in the torrid regions, could have existed in these northern parts of the globe. M. de Marschall endeavoured by one sweeping stroke of the fancy to solve this, as well as that of the extraordinary. fragments in which they are often imbedded, and held out that the whole have fallen at different times, like meteoric stones, from heaven.* The real difficulty, however, vanishes in a considerable degree, if not entirely, when we reflect, that although the torrid regions furnish us with some of these genera, they do not appear in any instance to contain the same precise species as are traced among the large fossil quadrupeds of the northern and colder parts: and hence it is no argument, that because the habits of the extant species do not qualify them for a residence in these latter regions, such situations might not have furnished a comfortable home to the species whose remains are found amongst us. The fossil species do not differ less from the living to which they make the nearest approach, than various animals that are familiar to us do from others that belong to the same tribes, and which are found, under one species or other, over the whole world. The race of horses, of swine, or of sheep, furnishes us with abundant examples of this remark: and that of dogs affords perhaps a still more striking illus-

* Recherches sur l'Origine, &c. Geissen, 1802.

tration; for while under one form, that of the *isatis* or Arctic fox, the canis *Lagopus* of Linnæus, we find it in the northermost coast of America, and even the frozen sea, living in clefts, or burrowing on the naked mountains, and in that of the almost infinite varieties of the c. *familiaris*, or domestic dog, in the bosom of our own country, — in the form of the c. *aureus*, chacal or jackal, we meet with it in the warmest parts of Asia and Barbary, prowling at night in flocks of one or two hundred individuals.

The extensive TURBARIES OF PEAT-FIELDS, which are so common to many parts of Europe, are produced by an accumulation of the remains of sphagnum and other aquatic mosses. These surround and cover up the small knolls upon which they are formed; or, in many places, descend along the vallies after the manner of the glaciers of Switzerland; but, while the latter melt away every year at their lower edges, the mosses are not checked by any obstacle in their regular increase; and as such increase takes place in determinate proportions, by sounding their depth to the solid ground we may form some estimate of their antiquity.

The ordinary rise of those extensive ranges of DOWNS, which are seen skirting the coasts of many countries, and especially where the shore is not very bold, is a mixt effort of sea and wind. To produce this, however, the soil that the sea washes over must consist of sand. This is first

pushed in successive tides towards the shore; it next becomes dry, by being left there at every reflux of the sea; and is then drifted up the beach, and to a considerable distance from the beach, by the winds which are almost always blowing from the sea, and often in whirls or eddies; and are at length fixed by the growth of wild plants, whose seeds are in like manner wafted about on the wings of the breeze, or casually dropped with the excretions of birds or other animals that pass over them. In several parts, observes M. Cuvier, these proceed with a frightful rapidity, overwhelming forests, houses, and cultivated fields in their irresistible progress. Those on the coast of the Bay of Biscay have actually buried a considerable number of villages whose existence is noticed in the records of the middle ages. And even in the present day they are threatening not fewer than ten distinct hamlets with almost inevitable destruction: one of which, named Mimigan, has been in perpetual danger for upwards of twenty years, from a sand-hill of more than sixty feet in perpendicular height, produced by the cause we are now contemplating, and which is very obviously augmenting. *

There are various forelands on the coasts of the North Sea, and particularly on those of the counties of Sleswigh and Holstein, which are

* Report concerning the downs of the Gulf of Gascony, or Bay of Biscay, by M. Tassin, Mont de Marsan, an. x. Cuvier, Theory of the Earth, § 31.

formed in the same manner.* But the most extraordinary inroads of sand-storms and sand-floods are, perhaps, those which have taken place in the Lybian Desert, and in Lower Egypt. M. Denon informs us, in his travels over this part of the world, that the summits of the ruins of ancient cities buried under mountains of drifted sands still appear externally; and that but for a ridge of mountains, called the Lybian Chain, which borders the left bank of the Nile, and forms a barrier against the invasion of these sands, the shores of the river, on that side, would long since have ceased to be habitable. "Nothing," says M. Denon, "can be more melancholy, than to walk over villages swallowed by the sand of the desert, to trample under foot the roofs of their houses, to strike against the tops of their minarets, and to reflect, that yonder, in days of yore, were cultivated fields, that hard by were groves of flourishing trees, and the dwellings of men close at hand; —and that all has now vanished." †

The various ISLANDS that spot the surface of the sea have arisen from different causes. Many of them have been merely separated from the adjoining continent by the inroad of the sea itself upon the main-land; others have been thrown up by volcanoes, which have at

* De Luc, Voyages Geologiques, tom. i.

† Jameson's Notes on Cuvier's Theory, &c. p. 217. Compare Dolomieu's Memoir on Egypt, in Journ. de Physique, tom. xlii.

times disgorged prodigious blocks of granite amongst the mixt materials, such as are frequently found in the Danish archipelago, in the midst of the *geest*, or alluvial matter, which has collected around them. Other islands are altogether the masonry of madrepores, and other coral zoophytes of wonderful industry and perseverance, of which the South Sea furnishes us with the largest and most astonishing specimens. These islands are for the most part flat and low, and surrounded by enormous belts of coral reefs. Most of the calcareous zoophytes are employed in their construction, but the principal worm is the madrepora *lubricata* of Linnæus.

In so large an abundance, and with so much facility, is calcareous matter elaborated by these, as well as by various other animals, and especially the testaceous worms, that M. Cuvier is inclined to ascribe all the calcareous rocks that enter into the solid crust of the earth to an animal origin.* But this is to suppose the earth of a far higher antiquity, and to have been the subject of more

* Some writers have proceeded much farther than this, for they have resolved all the solid materials of the earth's crust into an organic origin. Such was the opinion of Demaillet and Lamarck; who suppose that every thing was originally fluid; that this universal fluid gave rise to plants and animals; that all clay or argillaceous earth is the produce of the former, all calcareous earth of the latter, and that siliceous earth has been the result of the two. Telliamid, p. 169. Philosophie Zoologique, *passim*.

numerous general deluges, and inversions of sea and land, than are called for by the Wernerian system, or appear reconcileable with the Mosaic narrative. M. Cuvier apprehends, indeed, that such catastrophes may have occurred five or six times in succession, at a distance of four, five, or six thousand years from each other; and that even the chalk formation found in the basin of Paris originated in a revolution of this kind that occurred antecedently to that which is usually regarded as the flood of Noah. And, following up this idea, he conceives, towards the close of his Introductory Theory of the earth, that if the science of fossil organic productions could be carried to a much higher degree of perfection, we should be able to obtain far fuller information upon this subject; "and man, to whom only a short space of time is allotted upon the earth, would have the glory of restoring *the history of thousands of ages which preceded the existence of the human race*, and of thousands of animals that never were contemporaneous with his species."

LECTURE VII.

ON GEOLOGY.

(The subject continued.)

In our last study I attempted a brief sketch of the chief phænomena that occur to the eye of the geologist upon a survey of the solid crust of the earth, as far as he is able to penetrate into it. The conclusion to which such phænomena lead us is the following: that the rudimental materials of the globe, to the utmost depth we are able to trace them, existed at its earliest period, in one confused and liquid mass; that they were afterwards separated and arranged by a progressive series of operations, and an uniform system of laws, the more obvious of which appear to be those of gravity and crystallization; and that they have since been convulsed and dislocated by some dreadful commotion and inundation that have extended to every region, and again thrown a great part of the organic and inorganic creation into a promiscuous jumble.

Now the only two causes that can enter into the mind of man as being competent to the fluidity that appears at first to have existed throughout the whole crust of the earth are FIRE, or a peculiar SOLVENT. But, if a solvent, that

solvent must have been WATER: for there is no other liquid in nature in sufficient abundance to act the part of a solvent upon a scale so extensive.

And hence our enquiries into this subject become in some degree limited, and are chiefly confined to what have been called the PLUTONIC and the NEPTUNIAN hypotheses; the origin of the world in its present state from igneous fusion, and from aqueous solution. Both these theories are of very early date, and both of them have been agitated in ancient as well as in modern times with a considerable degree of warmth as well as of plausible argument.

Among the ancients, Heraclitus seems to have headed the advocates for the former theory, and Thales, or rather Epicurus, the supporters of the latter. In what may be regarded as modern times, Hooke may, perhaps, be held the reviver of the Plutonic system, which has since, as I have already observed, been supported by the cosmological doctrines of Buffon and Dr. Herschel. Its principal champions, however, in the present day, are Dr. Hutton, Professor Playfair*, and Sir James Hall; names, unquestionably, of high literary rank, and entitled to the utmost deference, but most powerfully opposed by the distinguished authorities of Werner, whose system I have just glanced at, Saussure, Kirwan, Cuvier,

* Illustrations of the Huttonian Theory of the Earth. Edinb. 1802.

and Jameson, not to mention that the general voice of geologists is very considerably in favour of the latter class of philosophers, and consequently of the Neptunian or aqueous hypothesis. Let us then take a brief view of each of these theories in their order.

According to the former, or the Plutonic conjecture, heat is the great source, not only of the original production, but of the perpetual reproduction of things. This theory supposes a regular alternation of decay and renovation. Of *decay* induced by the action of light, air, and other gasses, rain and other waters, upon the hardest rocks, by which they are worn down, and their particles progressively carried towards the ocean, and ultimately deposited in its bed; and of *renovation*, by means of an immense subterranean heat, constantly present at different depths of the mineral regions; which operates in the fusion and re-combination of the materials thus carried down and contained there, and afterwards in their sublimation and re-exposure to view in new strata of a more compact and perfect character. Hence the existing strata of every period consist, upon this theory, of the wreck of a former world, more or less completely fused and elevated by the agency of violent heat, and reconsolidated by subsequent cooling: of the general nature of which heat, however, we are still left in a considerable degree of ignorance. "It is not fire in the usual sense of the word," observes Mr. Playfair, "but heat, which is

required for this purpose; and there is nothing chimerical in supposing that nature has the means of producing heat, even in a very great degree, without the assistance of fuel or of vital air. Friction is a source of heat, unlimited for what we know in its extent; and so, perhaps, are other operations chemical and mechanical; nor are either combustible substances or vital air concerned in the heat thus produced. So, also, the heat of the sun's rays in the form of a burning glass, the most intense that is known, is independent of the substance just mentioned; and though the heat would not calcine a metal, nor even burn a piece of wood, without oxygenous gass, it would doubtless produce as high a temperature in the absence as in the presence of that gass."*

This subterranean heat, moreover, is supposed to derive a very considerable accession of power from the vast superincumbent weight that is perpetually pressing upon its materials; in confirmation of which a variety of curious experiments are appealed to, and especially a very ingenious set lately carried into effect and described by Sir James Hall, by which it has been rendered probable, that when the gasses of any fusible substance, as the carbonic acid of carbonate of lime, for example, are rendered incapable of flying off, a much less quantity of actual heat is sufficient for the purpose of fusion than when

* Illustrations of the Huttonian Theory, &c.

such gasses, freed from a heavy compression, can escape with facility. Now, the subterranean heat being supposed to exist at prodigious depths below the surface, the substances on which it operates must be so enormously compressed, as not only to render them easily fused, but in many instances to prevent their volatilization after the fusion has taken place; and from this circumstance it is possible, we are told, to explain a variety of appearances and qualities in minerals, and to answer a variety of objections which would otherwise weigh heavy against the general theory.

To the principle of an alternate decay and renovation, separated from the means by which they are supposed, upon this theory, to be accomplished, there seems to be no very serious objection. It is as readily allowed by the Neptunian as by the Plutonic geologist, that the strata of the earth are liable to waste, and are indeed perpetually wasting; and that the waste materials are carried forward to the sea. But the appearance of shells in limestone and marbles, in which the sparry structure is as perfect as in primary limestone, and through which are distributed veins of crystallized carbonate of lime, together with a variety of similar facts, fatally militate against the agency of heat as an universal cause; since, in such case, allowing it to have been sufficient to produce the general effect of crystallization, every vestige of the structure of the shells must have been destroyed,

and every atom of the carbonic acid totally evaporated.

It is, secondly, useless to argue, that there are other sources of heat than combustion or deflagration; because, admitting the fact to Mr. Playfair's utmost desire, it can be satisfactorily proved that all these sources are as little capable of acting in the interior parts of the globe, to the extent supposed in the theory before us, as combustion itself, which is relinquished by its defenders as incompetent to their purpose. But even allowing the full operation of all, or of any one of these causes, we have no method pointed out to us by which this subterranean heat is duly preserved and regulated — no controling power that directs it to the proper place at the proper season, without which it must be as likely to prove a cause of havoc and disorder as of renovation and harmony. It is useless, therefore, to pursue this theory any farther. In spite of the magnificence of its structure, the universality of its application, the plausibility of its appearance, and the talents with which it has been supported, it is built upon assumption alone; it lays down principles which it cannot support, and deals in fancy and conjecture rather than in solid facts and firm evidence.

Let us next, then, take a glance at the theory by which this is chiefly opposed, and which, as I have already observed, is denominated the NEPTUNIAN.

Under this hypothesis the two substances that were first evolved out of the general chaos on the formation of the earth, and chemically united to each other, were hydrogene and oxygene, in such proportion as to produce water, which is a compound of these substances, and in such quantity as to be able to hold every other material in a state of thin paste or solution. Of the materials thus held in solution granite is supposed to have been produced first, and in by far the greatest abundance. It hence, consolidated first, probably forms the foundation of the superficies of the globe, and perhaps the entire nucleus of the globe itself; and, as has been already seen, while it constitutes the basis of every other kind of rock, rises higher than any of them. It consists, as we have already observed, of felspar, quartz, and mica, all which must therefore have concreted by a crystallization nearly simultaneous; and from its containing no organic remains, it is obvious that it must have been formed prior to the existence of the animal and vegetable kingdoms. All the other rocks, upon this hypothesis, began to crystallize and consolidate after the formation of granite, in the order in which we have already traced them; and some of these before the whole of the granite was rendered perfectly firm, whence we trace beds of several of them in the granite formation itself; and as the same kind of action appears to apply to the whole, we, in like manner, trace beds of the newer rocks

successively in formations of those that are older; and, at last, remains of animal and vegetable materials, which are hence proved to have had an existence coetaneous with the newer classes.

The law of gravity appears to have operated through the whole of this process; and hence, water, as the least heavy material, must have risen to the surface, and purified itself by a filtration through the other materials, and at length collected in such hollows as were most convenient for its reception: these hollows constitute the bed of the ocean.

Water, thus collected in the cavity of the ocean, is carried by the atmosphere over the tops of the most elevated mountains, on which it is precipitated in rain, and forms torrents, by which it returns with various degrees of rapidity into the common reservoir. This restless motion and progress of the water in the form of rain or torrents gradually attenuate and wear away the hardest rocks, and carry their detached parts to distances more or less considerable; whence we meet with limestone, clay, quartz or flint, sand, and mineral ores, in places to which they do not naturally belong. The influence of the air, and the varying temperature of the atmosphere, facilitate the attenuation and destruction of these rocks. Heat acts upon their surface, and renders it more accessible, and more penetrable to the moisture, as it enters into their texture; the limestone rocks are reduced by

efflorescence, and the air itself affords the acid principle by which the efflorescence is continued. Such are a few of the numerous causes that contribute to the disunion of concrete bodies, and powerfully co-operate with that wonderful fluid which alternately forms and unforms; which creates, decomposes, and regenerates all nature.

The immediate effects of water in the shape of rain is to depress the mountains. But the materials which compose them must resist in proportion to their hardness; and hence we ought not to be surprised at meeting occasionally with peaks, which have stood firm amidst the wreck of ages, and still remain to attest the original level of the mountain-breadths which have disappeared. These primitive rocks, alike inaccessible to the assault of time and to that of the once animated beings which cover the less elevated heights with their relics, may be considered as the origin of streams and rivers. The water which falls on their summits flows down in torrents by their lateral surfaces. In its course it wears away the soil upon which it is incessantly acting. It hollows out channels of a depth proportioned to its rapidity, its quantity, and the hardness of the rock over which it passes, and at the same time carries along with it fragments of such stones as it loosens in its progress.

These stones, rolled by the water, strike together, and mutually break off their projecting angles; and hence we obtain collections of

rounded flints which line the beds of rivers, and of smaller pebbles which the sea is perpetually throwing upon the shores, often encrusted with a gravelly or calcareous edging. The powder which is produced by the rounding of the flints, or is washed down from the mountains, frequently stagnates, forms a paste, and agglutinates into fresh masses of the rocky matter of which it consists; often imbedding flints and other materials, and constituting compound substances known by the name of pudding-stones and grit-stones, which chiefly differ from each other in the coarseness or fineness of their grains, or in the cement which connects them. And if the water be loaded, as it often is, with minutely divided particles of quartz, it will proceed to crystallize whenever it becomes quiescent; and will form stalactites, agates, cornelians, rock-crystals, plain or coloured, according as it is destitute of or combined with any colouring material: and if the material with which the water be impregnated be lime instead of quartz, the crystallization will be calcareous alabaster, or marble.

Many of the earths are now known to be metallic oxydes, and all of them are suspected to be so: and hence a degree of heat capable of fusing them, and depriving them of the oxygene which gives them their oxyde form, will necessarily convert them into their metallic state. That such currents of heat, from electricity and other causes, are occasionally, and

perhaps in different places perpetually, existing beneath the surface of the earth, the Neptunian is as ready to admit as the Plutonic geologist; and hence the origin of metallic minerals, of mines, ores, ochres, and pyrites.

The decomposition of animal and vegetable matter contributes largely, moreover, in the view of the system now before us, to the changes which the globe is perpetually sustaining. The exuviæ of shell and coral animals is perpetually adding to the mass of its earths, and laying a foundation for new islands and numerous beds of limestone, in which we very often perceive impressions of the shells from which the soil has originated. On the other hand, we observe numerous quantities of vegetables, both submarine and superficial, heaped and deposited together by currents or other causes, constituting distinct strata, which progressively become decomposed, lose their organization, and confound their own principles with those of the earths. Hence the origin of pit-coal, and secondary schists or slates; to which, however, the decomposition of animal substances has also largely contributed. Hence, too, the formation and extrication of a variety of acids and alkalis, which have essentially administered to the actual phænomena of the face of the earth.

The action of volcanoes has contributed much in all ages, and is still contributing in our own, to the present state of the earth's surface. We have daily proofs of the mountains which it has

elevated, and have already noticed it as one source of the numerous islands that stud the face of the ocean; and we have just adverted to the subterranean agencies of electricity, heat, water, and other gasses and fluids which form its fuel. But the operation of volcanoes is more limited and local than that of the preceding agents. "They accumulate substances," says M. Cuvier, "on the surface that were formerly buried deep in the bowels of the earth, after having changed or modified their nature or appearances, and raise them into mountains; but they have never raised up nor overturned the strata through which their apertures pass, and have in no degree contributed to the elevation of the great mountains, which are not volcanic."

Inundations of seas and rivers have also, from time to time, added their tremendous force; but there is no ground for concluding that any catastrophe of this kind has been universal for the last four thousand years; nor, in fact, that such an event has ever occurred more than once since the earth has been rendered habitable.

In examining, then, the merits of the antagonist systems of geology before us, the Plutonic is perhaps best entitled to the praise of boldness of conception and unlimited extent of view. It aspires, in many of its modifications, not only to account for the present appearances of the earth, but for that of the universe; and traces out a scheme by which every planet, or system of planets, may be continued indefinitely, and per-

haps for ever, by a perpetual series of restoration and balance.

With this system the Neptunian forms a perfect contrast. It is limited to the earth, and to the present appearances of the earth. It resolves the genuine origin of things into the operation of water; and while it admits the existence of subterranean fires to a certain extent, and that several of the phænomena that strike us most forcibly may be the result of such an agency, it peremptorily denies that such an agency is the sole or universal cause of the existing state of things, or that it could possibly be rendered competent to such an effect.

More especially should we feel disposed to adhere to this theory, from its general coincidence with the geology of the Scriptures. The Mosaic narrative, indeed, with bold and soaring pinions, takes a comprehensive sweep through the vast range of the solar system, if not through that of the universe; and in its history of the simultaneous origin of this system touches chiefly upon geology, as the part most interesting to ourselves; but so far as it enters upon this doctrine, it is in sufficiently close accordance with the Neptunian scheme, — with the great volume of nature as now cursorily dipped into. The narrative opens, as I had occasion to observe in the lecture On Matter and a Material World, with a statement of three distinct facts, each following the other in a regular series, in the origin of the visible world. First, an abso-

lute creation, as opposed to a mere remodification of the heaven and the earth, which constituted the earliest step in the creative process. Secondly, the condition of the earth when it was thus primarily brought into being, which was that of an amorphous or shapeless waste. And, thirdly, a commencing effort to reduce the unfashioned mass to a condition of order and harmony. "In the beginning," says the sacred historian, "God CREATED the heaven and the earth. — And the earth was WITHOUT FORM AND VOID: and darkness was upon the face of the deep (or abyss). — And the spirit of God MOVED upon the FACE OF THE WATERS."

We are hence, therefore, necessarily led to infer that the first change of the formless chaos, after its existence, was into a state of universal aqueous solution; for it was upon the surface of the waters that the Divine Spirit commenced his operative power. We are next informed, that this chaotic mass acquired shape, not instantaneously, but by a series of six distinct days, or GENERATIONS, (that is epochs), as Moses afterwards calls them *; and apparently through the agency of the established laws of gravity and crystallization, which regulate it at the present moment.

It tells us, that during the first of these days, or generations, was evolved, what, indeed, agreeably to the laws of gravity, must have been evolved first of all, the matter of light and heat;

* Gen. ii. 4.

of all material substances the most subtle and attenuate; those by which alone the sun operates, and has ever operated, upon the earth and the other planets, and which may be the identical substances that constitute his essence.* And it tells us, also, that the luminous matter thus evolved produced light without the assistance of the sun or moon, which were not set in the sky or firmament, and had no rule till the fourth day or generation: that the light thus produced flowed by tides, and alternately intermitted, constituting a single day and a single night of each of such epochs or generations, whatever their length might be, of which we have no information communicated to us.

It tells us, that during the second day or generation uprose progressively the fine fluids, or waters, as they are poetically and beautifully denominated, of the firmament, and filled the blue etherial void with a vital atmosphere. That during the third day or generation the waters more properly so called, or the grosser and compacter fluids of the general mass, were strained off and gathered together into the vast bed of the ocean, and the dry land began to make its appearance, by disclosing the peaks or highest points of the primitive mountains; in consequence of which a progress instantly commenced from inorganic matter to vegetable organization, the surface of the earth, as well above as under the waters, being covered with plants and herbs, bearing

* Herschel, Phil. Trans. vol. lxxxiv.

seeds after their respective kinds; thus laying a basis for those carbonaceous materials, the remains of vegetable matter, which we have already observed are occasionally to be traced in some of the layers or formations of the class of primitive rocks, (the lowest of the whole), without a single particle of animal relics intermixed with them.

It tells us, that during the fourth day, or epoch, the sun and moon, now completed, were set in the firmament, the solar system was finished, its laws were established, and the celestial orrery was put into play; in consequence of which the harmonious revolutions of signs and of seasons, of days and of years, struck up for the first time their mighty symphony. That the fifth period was allotted exclusively to the formation of water-fowl, and the countless tribes of aquatic creatures; and, consequently, to that of those lowest ranks of animal life, testaceous worms, corals, and other zoophytes, whose relics, as we have already observed, are alone to be traced in the second class of rocks or transition-formations, and still more freely in the third or horizontal formations; these being the only animals as yet created, since the air and the water, and the utmost peaks of the loftiest mountains, were the only parts as yet inhabitable. It tells us, still continuing the same grand and exquisite climax, that towards the close of this period, the mass of waters having sufficiently retired into the deep bed appointed for them,

the sixth and concluding period was devoted to the formation of terrestrial animals; and, last of all, as the masterpiece of the whole, to that of man himself.

Such is the beautiful, but literal progression of the creation; according to the Mosaic account, as must be perceived by every one who will carefully peruse it for himself.

Of the extent, however, of the DAYS OR GENERATIONS that preceded the formation of the sun and moon, and their display in the sky or firmament, it gives us, as I have just observed, no information whatever. We only know that the flow of luminous matter which measured them advanced or was kindled up by regular tides; so that it alternately appeared and disappeared, commencing with a dawn and terminating with a dusk or darkness; for at the close of each it is said, "and the evening and the morning were the first day:" or, more literally, as indeed suggested in the marginal reading of our national version, "and there was evening and there was morning the first day;" that is, there was dusk and dawn, and by no means such an evening and morning as we have at present. And hence, Origen observes, that "no one of a sound mind can imagine there was an evening and a morning during the three first days without a sun." * So that the passage should, perhaps, be rendered, as most strictly it might be, "and there

* Περὶ Ἀρχῶν: in loc.

was dusk AS there was dawn, the first day.— ויהי ערב ויהי בקר יום אחד.

It has, indeed, been contended that each of these periods constituted a solar day, or a revolution of the earth round its own axis, and consequently answered to the measure of twenty-four hours, as at present. But to maintain this opinion it is necessary to suppose, that the sun and the moon were set in the sky "to rule over the day and over the night,"—"to divide the light from the darkness,"—and to "be for signs, and for seasons, and for days, and for years," on or before the very first day or generation; for otherwise there could be no solar day, or such as we have at present, produced by a revolution of the earth round her own axis. And there have not been wanting cosmologists and critics, as Whiston and Rosenmüller, who have maintained that the sun and the moon were created antecedently to the earth; that they had their stations allotted them in the heavens, and actually produced solar days and diurnal revolutions of the earth from the first. But though their own hypotheses require this, the idea is directly opposed to the spirit and the letter of the Mosaic narrative, and hence can in no respect be acceded to by any one who is anxious to preserve this narrative in its integrity and simplicity.

How much more explanatory and pertinent is the remark of our own excellent Bishop Hall,

when speaking of the primæval light, that during the first three days illuminated the face of nature: "Not," says he, "of the sun or stars, WHICH WERE NOT YET CREATED; but a common brightness only, to distinguish THE TIME, and to remedy the former confused darkness." And how admirably to the same effect does Bishop Beveridge thus express himself: "When he said, *let there be light*, by that word the light, WHICH WAS NOT BEFORE, BEGAN TO BE. But when he said, (that is three days or generations afterwards,) *let there be lights in the firmament, to divide the day from the night*, he thereby GAVE LAWS TO THE LIGHT he had before made, where he would have it BE, and what he would have it DO. This is what we call the law of nature: that law which God hath put into the nature of every thing; whereby it always keeps itself within such bounds, and acts according to such rules as God hath set it, and by that means shows forth the glory of his wisdom and power."

Nothing, indeed, can be clearer, than that, according to Moses, the sun and the moon were only set in the heavens during the fourth day or generation in the work of creation; and that, whatever may be the relative proportion of the times and the seasons, the light and the darkness, the day and the night, that have occurred subsequently, we have no reason to suppose they occurred in the same proportion

antecedently; since we are expressly told by the same inspired writer, that their immediate office, on being set in the sky, was to RULE these divisions of time, as they have ruled them, with a single miraculous exception or two, ever since, and to divide the light from the darkness, as it has since been divided.

We have no knowledge whatever, therefore, of the length of the first three or four DAYS or GENERATIONS that marked the great work of creation, antecedently to the completion of the sun and moon, and their appointment to their respective posts. And hence, for all that appears to the contrary, they may have been as long as the Wernerian system, and the book of nature, and I may add the term GENERATIONS, employed by Moses himself, seem to indicate.

Nor let it be supposed for a moment, that the term *day* in the Hebrew tongue seems to demand a limitation to the period of four and twenty hours, as it ordinarily imports; for there is no term in any language that is used with a wider latitude of construction than the Hebrew יום (*jom*), or its Arabic form يوم, which is the word for day in the original. We are constantly, indeed, employing this very word, as Englishmen, with no small degree of freedom, in our own age; for you will all allow me to drop the phrase "in our own AGE," and to adopt "in our own DAY" in its stead; thus making AGE and DAY terms of similar import. But in Hebrew

the same term is employed, if possible, in a still wider range of interpretation: for it not only denotes, as with ourselves, half a diurnal revolution of the earth, or a whole diurnal revolution, but in many instances an entire year, or revolution of the earth round the sun; and this not only in the prophetic writings, which are often appealed to in support of this remark, but in plain historical narrative as well. Thus in Exod. xiii. 10. the verse, "thou shalt keep this ordinance in its season *from year to year*," if literally rendered, would be "*through days of days*," or, "through *days upon days*," — מימים ימימה. And in like manner, Judges xvii. 16., "I will give thee ten *shekels* of silver *by the year*," if strictly interpreted, would be "*per dies* — *for the days*," — that is, "for the ANNUAL CIRCLE of days," — לימים.

Sometimes, again, the Hebrew יום, or day, comprises the whole term of life, as in 1 Chron. xxix. 15.

> Our DAYS (ימינו) on earth are a shadow,
> And there is none abiding.

So again, Job, xiv. 6.

> Turn from him that he may rest,
> Till he shall accomplish, as an hireling, his DAY—יומו.

But the clearest and most pertinent proof of the latitude with which the term יום, or DAY, is employed in the Hebrew scriptures, is in the very narrative of the creation before us: for after having stated in the first chapter of Genesis that

the work of creation occupied a period of SIX DAYS, the same inspired writer, in recapitulating his statement ch. ii. 4., proceeds to tell us, "these are" — or rather, "*such were* the GENERATIONS of the heavens and of the earth when they were created; IN THE DAY (ביום) that the Lord God made the earth and the heavens." In which passage Moses distinctly tells us that, in the preceding chapter, he has used the term יום DAY in the sense of generation, succession, or epoch; while we find him here extending the same term DAY to the whole hexaemeron, the entire term of time, whatever it may be, that these six days or generations filled up. So that the sense given to the word by Moses, instead of limiting us to the idea of twenty-four hours' duration, naturally leads us to ascribe, not only a different, but a much enlarged extent of time to the divisions he has marked by the word יום, or DAY: or at least to those terms which occurred before the government of the sun and the moon was established, and the heavenly orrery commenced its harmonious action.

Whether, indeed, the days from this last period, constituting the fifth and sixth, were of a different length from any of the preceding, which may also have differed from each other, and were strictly diurnal revolutions of twenty-four hours, it is impossible exactly to determine. But it is a question which by no means affects the actual face of nature or the geological system before us: for as the third or horizontal series of rocks

in which petrifactions of KNOWN animal and vegetable substances begin to make their appearance must have continued to augment for ages after the completion of the hexaemeron, or six epochs of creation, whatever be the duration assigned to them; and as the two loftiest, the fourth and fifth sets of rocks, or the alluvial and volcanic, are still forming, and have been ever since the great work of creation was completed, the precise duration of the two last days of creative labour can have no influence upon this question. But to a plain yet attentive reader of the Mosaic account even these two days must, I think, appear to have been of a far more protracted length than that of twenty-four hours each, and especially the sixth day; for it is difficult to conceive how the first parent of mankind could have got through the vast extent of work assigned to him within the short term of twelve or fourteen hours of day-light, without a miracle, which is by no means intimated to us, and as difficult to suppose that he was employed through the night. On this last day were created, as we learn from Gen. i. 24—28., all the land-animals after their kind, cattle, and wild beasts and reptiles; then Adam himself, but alone; who was next, as we learn from ch. ii. 15—22., taken and put into the garden of Eden, *to dress it and to keep it;* where he had explained to him the trees he might eat of, and the tree he might not; after which were brought to him, that he might make himself acquainted with their respective natures, every

beast of the field and every fowl of the air; to all of whom he gave names as soon as their respective characters became known to him. Subsequently to which (for at this time, v. 20., there was not found a help meet for him) he was plunged into a deep sleep, when the woman was formed out of a part of himself, which completed the creative labour of this last day alone.

That the same Almighty Power who created light by a word, saying יהי אור ויהי אור "be light! and light was*" could have ruled the whole of this, or even formed the universe, by a word, as well, is not to be doubted; but as both the book of revelation and the book of nature concur in telling us that such was not the fact, and that the work of creation went on progressively, and under the influence of a code of natural laws, we are called upon to examine into the march of this marvellous progress by the laws of nature referred to, and to understand it by their operations. Nor is it more derogatory to Him with whom a thousand years are as one day, and one day as a thousand years, to suppose that He allotted six hundred or six thousand years to the completion of his design, than that He took six solar days for the purpose; and surely there is something far more magnificent in conceiving the world to have gradually attained form, order, and vitality, by the mere operation of powers communicated to it in a state of chaos,

* Gen. i. 3.

through a single command, which instantly took effect and commenced, and persevered and perfected the design proposed, than in conceiving the Almighty engaged in personal and continuous exertions, though for a more limited period of time.

Thus, in progressive order, uprose the stupendous system of the world: the bright host of morning stars shouted together on its birth-day; and the eternal Creator looked down with complacency on the finished fabric, and "saw that it was good."

LECTURE VIII.

ON ORGANIZED BODIES, AND THE STRUCTURE OF PLANTS COMPARED WITH THAT OF ANIMALS.

From the unorganized world, which has formed the main subject of our two last lectures, let us now rise a step higher in the scale of creation; and ascend from insentient matter to life, under the various modifications it assumes, and the means by which it is upheld and transmitted.

If I dig up a stone, and remove it from one place to another, the stone will suffer no alteration by the change of place; but if I dig up a plant and remove it, the plant will instantly sicken, and perhaps die. What is the cause of this difference? Both have proceeded from a minute molecule, a nucleus or a germ; both have a tendency to preserve their derivative or family configuration, and both have been augmented and perfected from one common soil. If I break the stone to pieces, every individual fragment will be found possessed of the characteristic powers of the aggregate mass; it is only altered in its shape and magnitude: but if I tear off a branch from the plant, the branch will in-

stantly wither, and lose the specific properties of the parent stock.

No external examination, or reasoning *à priori*, will explain this difference of effect. It is only by a minute attention to the relative histories, interior structures, and modes of growth of the two substances, that we are enabled to offer any thing like a satisfactory answer; and by such examination we find that the stone has been produced fortuitously, has grown by external accretion, and can only be destroyed by mechanical or chemical force; while the plant has been produced by generation, has grown by nutrition, and been destroyed by death: that it has been actuated by an internal power, and possessed of parts mutually dependent and contributary to each other's functions.

In what this internal power consists we know not. Differently modified, we meet with it in both plants and animals; and wherever we find it we denominate it the *principle of life*, and distinguish the individual substance it actuates by the name of an *organized being*. And hence, all the various bodies in nature arrange themselves under the two divisions of organized and unorganized: the former possessing an origin by generation, growth by nutrition, and a termination by death; and the latter a fortuitous origin, external growth, and a termination by chemical or mechanical force.

This distinction is clear, and it forms a boundary that does not seem to be broken in upon

by a single exception. In what, indeed, that wonderful power of crystallization consists, or by what means it operates, which gives a definite and geometrical figure to the nucleus or primary molecule of every distinct species of crystal; and which, with an accuracy that laughs at all human precision, continues to impress the same figure upon the growing crystal through every stage of its enlargement, thus naturally separating one species from another, and enabling us to discriminate each by its geometrical shape alone—we know not: but even here, where we meet with an approach towards that formative effort, that internal action and consent of parts which peculiarly characterize the living substance, there is not the smallest trace of an organized arrangement; while the origin is clearly fortuitous, and the growth altogether external, from the mere apposition of surrounding matter.

So, on the other hand, in corals, sponges, and fuci, which form the lowest natural orders among animals and vegetables, and the first of which seems to constitute the link that connects the animal and vegetable with the mineral world, for it has in different periods been ascribed to each,—simple as is their structure, and obtuse as is the living principle that actuates them, we have still sufficient marks of an organized make; of an origin by generation, the generation of buds or bulbs, of growth by nutrition, and of termination by death.

But the animal world differs from the vegetable as widely as both these differ from the mineral. How are we to distinguish the organization of animals from that of plants?—In what does their difference consist? And here I am obliged to confess, that the boundary is by no means so clearly marked out; and that we are for the most part compelled to characterise the difference rather by description than by definition. Nothing, indeed, is easier than to distinguish animals and vegetables in their more perfect states: we can make no mistake between a horse and a horse-chesnut tree, a butterfly and a blade of grass. We behold the plant confined to a particular spot, deriving the whole of its nutriment from such spot, and affording no mark either of consciousness or sensation; we behold the animal, on the contrary, capable of moving at pleasure from one place to another, and exhibiting not only marks of consciousness and sensation, but often of a very high degree of intelligence as well. Yet, if we hence lay down consciousness or sensation, and locomotion, as the two characteristic features of animal life, we shall soon find our definition untenable; for while the Linnean class of worms affords instances, in perhaps every one of its orders, of animals destitute of locomotion, and evincing no mark of consciousness or sensation, there are various species of plants that are strictly locomotive, and that discover a much nearer approach to a sensitive faculty.

However striking, therefore, the distinctions between animal and vegetable life, in their more perfect and elaborate forms, as we approach the contiguous extremities of the two kingdoms we find these distinctions fading away so gradually,

Shade, unperceived, so softening into shade,

and the mutual advances so close and intimate, that it becomes a task of no common difficulty to draw a line of distinction between them, or to determine to which of them an individual may belong. And it is probable, that that extraordinary order of beings called zoophytes, or animated plants, as the term imports, and which by Woodward and Beaumont were arranged as minerals *, and by Ray and Lister as vegetables, have at last obtained an introduction into the animal kingdom †, less on account of any other property they possess, than of their affording, on being burnt, an ammoniacal smell like that which issues from burnt bones, or any other animal organs, and which is seldom or never observed from burnt vegetable substances of a decided and unquestionable character. Ammonia, however, upon destructive distillation, is met with in small quantities in *particular parts* of most if not of all vegetables, though never perhaps in the whole plant. Thus it occurs slightly in the wood or vegetable fibre; in extract, gum-mucilage, camphor, resin, and balsam;

* Phil. Trans., xiii. 277.

† Parkinson's Organic Remains, i. 23. ii. 157, 158.

gum-resin, gluten, and caoutchouc: besides those substances that are common to both animals and vegetables, as sugar, fixed oil, albumen, fibrine, and gelatine. There are some plants, however, that even in their open exposure to a burning heat give forth an ammoniacal smell closely approaching to that of animal substance. The clavarias or club-tops, and many other funguses, do this. But a distinction in the degree of odour may even here be observed, if accurately attended to. Yet the clavarias were once regarded as zoophytes, and are arranged by Millar in the same division as the corals and corallines.*

M. de Mirbel, in his very excellent treatise

* Several species of this genus of fungi have very singular properties: thus, the c. *hæmatodes* has so near a resemblance to tanned leather, though somewhat thinner and softer, as to be named *oak-leather club-top,* from its being chiefly found in the clefts and hollows of oak-trees. In Ireland, it is employed as leather to dress wounds with; and, in Virginia, to spread plasters upon.

There are some cryptogamic plants, and especially among the mosses, that can be hardly made to burn by any means. Such is the fontinella *antipyretica,* so called on this very account: and which is hence in common use among the Scandinavians, as a lining for their chimney sides, and the inside of their chimnies, by way of preservation. So that here we have an approach to mineral instead of to animal substances, and especially to the asbestos and other species of talcose earths. There is one species of byssus, another curious genus of mosses, that takes the specific name of asbestos, from this very property. It is found in the Swedish copper mines of Westmann-land in large quantities; and when exposed to a red heat, instead of being consumed, is vitrified.

"On the Anatomy and Physiology of Plants," has endeavoured to lay down a distinction between the animal and the vegetable world in the following terms, and it is a distinction which seems to be approved by Sir Edward Smith: "Plants alone have a power of drawing nourishment from inorganic matter, mere earths, salts, or airs; substances incapable of nourishing animals, which only feed on what is or has been organized matter, either of a vegetable or animal nature. So that it should seem to be the office of vegetable life alone to transform dead matter into organized living bodies."* Whence another learned French physiologist, M. Richerand, has observed that the aliments by which animals are nourished are selected from vegetable or animal substances alone; the elements of the mineral kingdom being too heterogeneous to the nature of animals to be converted into their own substance without being first elaborated by vegetable life; whence plants, says M. Richerand, may be considered as the laboratory in which nature prepares aliment for animals.†

I concur with these elegant writers in admitting the beautiful and harmonious relation so obviously established between minerals, plants, and animals; but it is at the same time impossible to allow of the distinction between vegetable and animal life here laid down; because, first,

* Traité d'Anatomie et de Physiologie vegetale, i. 19.

† Elemens de Physiologie, &c. cap. de la Digestion.

vegetables are by no means nourished exclusively, as indeed M. Mirbel himself frankly allows, from terrene elements; and secondly, because animals are as little nourished exclusively from vegetable materials. Among insects, worms, and even fishes, there are many tribes that derive by far the greater portion of their increase from the mineral kingdom alone; while even in man himself, air, water, common salt, and lime, which last is almost always an ingredient of common salt, are substances indispensable to his growth, and are derived immediately from the mineral kingdom.

In laying down, therefore, a distinctive character for animals and plants, we are compelled to derive it from the more perfect of each kind; and to leave the extreme cases to be determined by the chemical components eliminated on their decomposition. And under this broad view of the subject I now proceed to observe, that while they agree in an origin by generation, a growth by nutrition, and a termination by death; in an organized structure, and an internal living principle; they differ in the powers with which the living principle is endowed, and the effects it is capable of exerting. In the plant it is limited, so far as we are capable of tracing it, to the properties of irritability, contractility, and simple instincts; in the animal it superadds to these properties those of muscularity, sensation, and voluntary motion.

There have been, indeed, and there still are, physiologists who,— not adverting to the extra-

ordinary effects which the power of irritability is capable of producing when roused by different stimulants, and under the influence of an internal and all-pervading principle of life, operating by instinctive laws and instinctive actions, or those, as we shall show hereafter, which are specially directed to the growth, preservation, or reproduction of a living frame, or any particular part of it, — have conceived plants as well as animals to be possessed of sensation and muscular fibres; and as sensation is the result of a particular organ, and the organ producing it is connected with various others, have at the same time liberally endowed them with a brain, a heart, and a stomach; and have very obligingly permitted them to possess ideas, and the means of communicating ideas; to fall in love and to marry, and thus far to exercise the distinctive faculty of volition. The whole of which, however, is mere fancy, grounded altogether upon an erroneous and contracted view of the effects of the principle of irritability when powerfully excited by the influence of light, heat, air, moisture, and other causes.

In reality, such kinds of loves and intermarriages are not peculiar to plants, but are common to all nature: they exist between atom and atom, and the philosopher calls them attractions; they exist between congeries and congeries, and the chemist calls them affinities; they exist between the iron and the loadstone, and every one denominates them magnetism. Nor

let it be said that in these cases of mutual union we have nothing more than a mere aggregation of body; for we have often a third substance produced, and actually generated, as the result of such union, far more discrepant from the parent substances both in quality and feature than are ever to be met with in vegetable or animal life. Thus if an acid be married to an alkali, the progeny brought forth will be a neutral salt, possessing not the remotest resemblance to the virtues of either of its parents. In like manner if alkohol be married to any of the more powerful acids, and the banns be solemnized over an altar of fire, but not otherwise, the offspring engendered will be a substance called ether, equally unlike both its parents in its disposition. But the form or features are as frequently changed as the temper. Thus, if we unite olive oil, which is a liquid, with some of the oxydes of lead which are powders, the result is neither a liquid nor a powder, nor a medium of the two, which would be a paste, but the hard adhesive plaster usually called diachylon. So, again, if muriatic acid, which is a liquid, sport in dalliance with the volatile nymph ammonia, which is an invisible gass, the fruit of their embraces will be still more extraordinary in point of form, for the gass and the liquid will engender that solid substance commonly known by the name of sal ammoniac, or, in the new nomenclature, muriate of ammonia. In like manner our common smelling salts, or carbonate of ammonia, though a hard concrete

crystallization, are the mere result of the union of two invisible gasses, ammonia and carbonic acid gass, or fixed air; and which, having duly paid their court to each other, give birth to this solid substance.

But in all this it may be said that we have no instance of a multiplication of species; nor in reality of any thing more than the production of a third substance, issuing, like the fabled phœnix of antiquity, out of the ashes or decomposition of the parent stock; yet in many cases we have instances of multiplication also — and instances far more extraordinary and far more prolific than are ever to be found in the multiplication of either animals or vegetables. Such especially are those wonderful increases that occur in the case of ferments and of contagions. A few particles of yeast lying dormant in a desert-spoon are introduced into a barrel of beer, or of any other fermentable fluid, and in a few hours propagate their kind through the largest vessel that was ever manufactured; so that at length every particle of the fluid is converted into a substance of their own nature. A few pestilential miasms are thrown forth from a stagnant marsh or a foul prison, and give birth instantaneously to myriads and myriads of the same species of particles, till the atmosphere becomes impregnated with them through a range of many miles in diameter. Two or three particles of the matter of plague are packed up in a bag of cotton at Aleppo, and are many months

afterwards set at liberty in Great Britain. Aided by the stimulus of the air, they instantly set to work, and procreate so rapidly that the whole country in less than a week is laid prostrate by the enormity of their increase.

Now the terms loves and marriages will just as well apply to all these as to the vegetable creation. The cause of the respective unions, and of the changes that take place in consequence of such unions, are in both cases nothing more than elective attractions: in the mineral and gasseous kingdoms produced by what chemists have denominated the principle of *affinity*, and in the vegetable by what physiologists have called the principle of *irritability*, a principle far nicer and nobler and more delicate than that of affinity, and under the influence of an internal, an all-pervading and identifying vital power, capable, as differently excited by different stimulants, of producing far nicer and nobler, more delicate and more complicated effects; but which in itself is not more different from the principle of *affinity* than it is from that of *sensation*.

No experiment or observation has hitherto proved vegetables to be possessed of any higher powers than those of irritability, contractility, and those instinctive energies which we shall hereafter show are dependent upon the principle of life.

It is almost superfluous to observe, in this place, that there are also powers and faculties of

a much higher character than any I have yet noticed, appertaining to the nobler ranks of animals; for at present I am only pointing out the leading characters by which animals in general may be distinguished from vegetables in general, and shall have sufficient opportunities, as we proceed, of adverting to these additional faculties, and of investigating their respective excellencies.

Our immediate concern, then, is with VEGETABLE LIFE; its general laws, structure, and phænomena. And upon this subject I shall touch as briefly as possible, intending it as a mere vestibule, or introduction to the more important study of animal philosophy.

Plants, then, like animals, as I have already observed, are produced by generation, and through the medium of ova, or eggs. The exceptions to this common rule are few, and they occur equally in both kingdoms. The egg of the plant is its seed; a doctrine not of modern origin, but taught and understood quite as clearly, and with as close a reference to the rise of animal life, by the ancients, as in the present day.* The seed is

* Οὕτω δ' ᾠοτοκεῖ μακρὰ δένδρεα πρῶτον ἐλαίας

Empedocles.

So plants, like animals, uprise to air,
And in green eggs young olives olives bear.

And upon this beautiful verse, which he has preserved as a fragment, Aristotle remarks, τό τε γὰρ ᾠὸν κύημα ἐστὶ, καὶ ἐκ τίνος αὐτοῦ γίγνεται το ζῶον. "For the egg is the conception, and after the same manner the animal is created." *De Generat Animal.* i. 23.

sometimes naked, but more generally covered with a pericarp, whence plants become naturally divided into the two grand arrangements of gymnospermous, and angiospermous. The pericarp is of various forms and structures; and of these the more common are the legume, silique, or silicle, being merely varieties of what, among ourselves, is donominated in popular language cod or pod; the loment, which is a kind of pod not so frequent as either of the former, but of which we have an instance in the mimosas and the cassia *Fistula;* the pome or core-apple, of which we have instances in the common apple and the pear; the drupe, or stone-apple, instances of which occur to us in the plum, cherry, and almond; the glume or chaff; the berry; the acinus or conglomerate berry, as in the rasp; the nut; and the capsule. *

Stripping off this outer covering, we find the seed to consist internally of a *corculum*, or heartlet, and externally of a fleshy or parenchymatous substance, surrounded with a double integument, sometimes single, sometimes bifid, and sometimes more than bifid; and hence denominated monocotyledonous, dicotyledonous, polycotyledonous. In popular language these are called seed-lobes, or seed-leaves: and in the phaseolus *vulgaris*, or common kidney-bean, we have as striking an instance as in any plant, and which

* Compare Knight's general theory of vegetable physiology, Horticultural Transactions, vol. i. p. 217, with Nicholson's Journal, vol. xxxii p. 350.

every one must have noticed, just peeping in two distinct segments above the ground, as soon as the seed has begun to germinate. It was very generally supposed formerly, and is still supposed by some botanists, that the seeds of various orders of plants, as the mosses, fungi, and algæ, are acotyledonous, or totally destitute of a cotyledon of any kind. But as many, perhaps most, plants of this kind have of late been found to possess some such parenchyma, we have great reason for believing that this organ is universal, and that there is no such thing as an acotyledonous seed in the whole vegetable kingdom. In reality, the cotyledon appears absolutely necessary for the germination and future growth of the seed, and may hence be denominated its lungs or placentule. Like the perfect plant, it possesses lymphatics and air-vessels. Through the former of these it absorbs the moisture of the soil into which it is plunged, decomposes a part of it into its elementary principles, and conducts those principles, together with the undecomposed water, to the corcle or heartlet, which becomes stimulated to the process of germination by the oxygene thus set at liberty.

Mrs. Ibbetson has attempted to prove that the cotyledon is of no use whatever for the purpose of nourishment; which, according to her observations, is only conveyed to the corcle by what she calls a system of nourishing vessels, altogether distinct from the cotyledon. It is

not very clear, however, what is here meant by nourishing vessels; nor can we for a moment admit that so large an organ as the cotyledon, and apparently so important, can be designed for no other office, than merely, as this lady conjectures, to screen the primordial leaves from the light and air on their first formation. *

According to Mr. Mirbel's experiments, as detailed in the Memoirs of the National Institute, the soil and the albumen in the cotyledon are both concerned in the developement of the germ; and both continue to contribute conjointly till the albumen is entirely absorbed: at which time the plant has strength enough to derive from the soil or the atmosphere the nourishment it requires from this period. In this respect the albumen of the cotyledon corresponds with the vitellus of the hen's egg.

In marine plants that are destitute of a radicle, as the water caltrop (trapa *natans*), the germ must necessarily be supported in the first instance by means of the cotyledon.

It is the corcle which is the true *punctum saliens* of vegetable life, and to this the cotyledon is subservient. The corcle consists of two parts, an ascending and a descending; the former called its plumule, which gives birth to the trunk and branches; the latter named its rostel, which gives birth to the root and radicles. The position of the corcle in the seed is always

* Nicholson's Journal, vol. xxvii. 9.

in the vicinity of the *hilum* or eye, which is a cicatrix or umbilicus remaining after the separation of the *funis* or umbilical cord from the pericarp, to which the seed has hereby been attached. The first radicle or germinating branch of the rostel uniformly elongates, and pushes into the earth, before the plumule evinces any change. Like the cotyledon, the radicles consist chiefly of lymphatics and air-vessels, which serve to separate the water from the soil, in order that the oxygene may be separated from the water.

Hence originates the root, unquestionably the most important part of the plant, and which in some sense may be regarded as the plant itself: for if every other part of the plant be destroyed, and the root remain uninjured, this organ will regerminate and the whole plant be renewed; but if the root perish, the plant becomes lost irrecoverably. Yet there are various phænomena in vegetable life that manifest a smaller difference in the nature of the root and the trunk, than we should at first be induced to suppose; for Willoughby observed, more than a century and a half ago *, that in several species, and especially those of the prunus and salix, cherry and willow tribes, if the stem branches be bent down to the earth, plunged into it, and continued in this

* Phil. Trans. year 1669, iv. p. 963. — 1670, v. p. 1165. 1168. 1199. — 1671, vi. p. 2119.

situation for a few months, these branches will throw forth radicles; and if, after this, the original root be dug up, and suffered to ascend into the air, so that the whole plant become completely inverted, the original root will throw forth stem-branches and bear the wild fruit peculiar to its tribe. The rhizophora *Mangle*, or mangrove-tree, grows naturally in this manner; for its stem-branches, having reached a certain perpendicular height, bend downwards of their own accord, and throw forth root-branches into the soil, from which new trunks arise, so that it is not uncommon, in some parts of Asia and Africa, to meet with a single tree of this species covering the oozy waters in which it grows with a forest of half a mile in length. The ficus *Indica*, or banyan, grows in the same manner, and often with enormous trunks, equally derived from a primary root. The largest tree of this kind known to Europeans, is on an island in the river Nerbedda in the Guzzerat, distinguished in honour of a Bramin, of high reputation, by the name of Cubbeer Bur. High floods have destroyed many of its incurved stems, yet its principal stems measure two thousand feet in circumference, the number of its larger trunks, each exceeding the bulk of our noblest oaks, amount to three hundred and fifty, while that of its smaller are more than three thousand; so that seven thousand persons may find ample room to repose under its enormous shade, and

may at the same time be richly supplied from the vast abundance of fruit which it yields in its season.

The solid parts of the trunk of the plant consist of CORTEX, cuticle, or outer bark; LIBER, CUTIS, or inner bark; ALBURNUM, or soft wood; LIGNUM, or hard wood *; and MEDULLA, or pith. Linnéus gave the name of medulla to the pith of plants, upon a supposition that it had a near resemblance to the medulla spinalis of quadrupeds. A closer investigation, however, has since proved that this resemblance is very faint, and that the pith or medulla of vegetables consists of nothing more than a mere spongy

* There is a curious paper of Count Rumford's mentioned among the labours of the French Imperial Institute for 1812, upon the chemical properties of the different parts entering into the composition of the trunk of trees, for an account of which see also Thomson's Annals of Philos. vol. i. p. 386. By a variety of experiments Count Rumford was led to this singular conclusion, that the specific gravity of the solid matter which constitutes the *timber* of wood is almost the same in all trees. By the same means he determined that the woody part of oak in full vegetation is only four-tenths of the whole. Air constitutes one-fourth of it, and the rest consists in sap. Light woods have still a much less quantity of solid matter: but the season of the year and the age of the tree occasion considerable variations. Ordinary dry wood contains about one-fourth of its weight of water. Even the oldest wood, though in the state of timber for ages, never contains less than one-sixth of its weight of water. All absolutely dry woods give from 42 to 43 per cent. of charcoal: whence he concludes, that the ligneous matter is identic in all woods.

cellular substance, forming indeed an admirable reservoir for moisture; and hence of the utmost importance to young plants, which, in consequence of their want of leaves and branches whose surfaces are covered with the bibulous mouths of innumerable lymphatics, would otherwise be frequently in danger of perishing through absolute drought; but gradually of less use as the plant advances in age, and becomes possessed of these ornamental appendages; and hence, except in a few instances, annually encroached upon, and at length totally obliterated by the surrounding lignum.

All these lie in concentric circles; and the trunk enlarges, by the formation of a new liber or inner bark every year; the whole of the liber of one year, excepting indeed its outermost layer, which is transformed into cortex, becoming the alburnum of the next, and the alburnum becoming the lignum. Such, at least, is the common theory, and which seems to be well supported by the experiments of Malpighi and Grew: but it has lately been controverted by Mr. Knight, who contends, that the liber has no concern in the formation of new wood, which proceeds from the alburnum alone, a new layer of alburnum being formed for this purpose annually. I cannot discuss the argument at present: nor is it of any great importance; since, under either system, it is obvious that a mark of any kind, which has penetrated through the outer into the inner bark, must in a long process of years be

comparatively transferred to the central parts of the trunk. On which account we often find, in felling trees of great longevity, as an oak, for example, the date of very remote national æras, and the initials of monarchs who flourished in very early periods of our national history, stamped in the very heart of the timber on its being subdivided.

Some of these memorials are very curious, and M. Klein, the well-known Secretary of Dantzic, has given various examples in his letter to Sir Hans Sloane, bart., the President of the Royal Society.* One of these consists of a long series of letters discovered, in 1727, in the trunk of a full-grown beech, near Dantzic, in land belonging to the family of Daniel Berckholtz. The letters D. B. were chiefly conspicuous in the solid wood; the wood towards the bark, and that towards the heart, that is, in each extremity, "bearing not the least trace of letters." M. Klein relates another example from the Ephemerides of Natural Curiosities †, recorded by Joannes Myerus. It consists of a thief hanging from a gibbet, apparently drawn by nature's own pencil in the timber of a beech-tree; as also the figure of a crucified man, found in a tree of the same kind; and that of a chalice with a sword, perpendicularly erect, sustaining a crown on its

* Phil. Trans. for 1739, vol. xli. p. 231.

† Ephem. Nat Cur, decad. iii.-an. v. obs. 29.

point; which was preserved at the Hague, and had been seen by himself.

Such marks were formerly attributed to miraculous intervention, or regarded as marvellous sports of nature: but the hints now offered will easily explain their origin.

Foreign substances have often been found imbedded in the same way, having at one time been sunk into the inner bark, or penetrated it by a wound or other excavation, and afterwards covered over with new annual growths of liber and alburnum. Thus Sir John Clerk gives an account of a horn of a large deer which was found in the heart of an oak in Whinfield Park, Cumberland, fixed in the timber with large iron cramps, with which, of course, it had been fastened on.* And we are hence able to account for the occasional detection of a capricorn beetle †, or other insect which has been found in the centre of a trunk, the animal having crept into an accidental cleft, and either died there naturally, or been arrested and imprisoned by the secretion of the matter of new inner bark while in the torpitude of its aurelian state. And hence, indeed, the cause of the very wonderful phænomena of toads or frogs being at times found in a like situation; having in the same way been impacted in the hole or crack into

* Phil. Trans. for 1740, vol. xli. p. 418.

† Id. 1741, vol. xli. p. 861.

which they had crept, by the glutinous fluid of the inner bark, during sickness or a protracted winter sleep. Some of these are found alive when the tree is cut down, deriving both air and nutriment enough from the surrounding vessels of the tree during their imprisonment. In the Mémoirs of the Paris Academy there is an example of a toad found in a tree that was proved to be a century old.*

As the series of concentric circles, produced in the trunk of a tree by the growth of every year, are still visible after the conversion of every other part into lignum, or hard wood, we can trace its age with a considerable degree of certainty, by allowing a year for every outer circle, and about two or three years for the complete lignification of the innermost.†

Independently of these more solid parts of the trunk or stem, we generally meet with some portion of parenchyma and cellular substance, and always with the different systems of vegetable vessels disposed in one common and uniform arrangement. The lower orders of plants, indeed, such as the annuals and biennials, consist almost exclusively of parenchyma or cellular

* Mem. de l'Acad. Par. 1731, p 24.

† The palms form an exception to this general rule, possessing neither proper bark, nor fascicles of vessels displayed in any circular form: the bark being produced by a remnant of the leaves, and the vessels running in a straight line without regular order, and surrounded by cellular substance.

substance, with an inner and outer bark, and the respective vessels of the vegetable system.

These vessels are adducent and reducent, or arteries and veins, lacteal or sap-vessels, and lymphatics. Many of these may be seen by the naked eye, and especially the sap-vessels: and the vascular structure of the whole has been sufficiently proved by Gessner, by means of the air-pump. The reducent or returning vessels are stated, by Sir E. Smith, to bring back the elaborated sap from the leaves to the liber for the new layer of the existing year.*

The lymphatics lie immediately under the cuticle and in the cuticle. They anastomose in different ways through their minute intermediate branches, and, by surrounding the apertures of the cuticle, perform the alternating economy of inhalation and exhalation. Their direction varies in different species of plants, but is always uniform in the same species.

Immediately below these lie the adducent vessels or arteries; they are the largest of all the vegetable vessels, rise immediately from the root, and communicate nutriment in a perpendicular direction: and, when the stem of a plant is cut horizontally, they instantly appear in circles. Interior to these lie the reducent vessels or veins; which are softer, more numerous, and more minute than the arteries; and in young

* Introd. to Botany, p. 56. See also Wildenow's Introd. p. 236

shoots run down through the cellular texture and the pith. Between the arteries and veins are situated the *air-vessels*, as they were formerly called; but which Dr. Darwin and Mr. Knight have sufficiently succeeded in proving to contain, not air in their natural state, but sap.* They seem to be the true genuine lacteals issuing from the root, as, in animals, they issue from the villous coating of the intestinal canal. They are delicate membranous tubes, stretching in a spiral direction, the folds being sometimes close to each other, and sometimes more distant, but generally growing thicker towards the root, and especially in ligneous plants. These vessels also are very minute, and, according to numerous observations of Hedwig made with the microscope, seldom exceed a 290th part of a line, or a 3000th part of an inch in diameter.

The lymphatics of a plant may be often seen with great ease by merely stripping off the cuticle with a delicate hand, and then subjecting it to a microscope; and in the course of the examination we are also frequently able to trace the existence of a great multitude of valves, by the action of which the apertures of the lymphatics are commonly found closed.† Whether the other systems of vegetable vessels possess the same mechanism, we have not been able to de-

* See Smith's Introd. p. 47.

† This seems to acquire additional probability from Mr. Knight's experiments. See Phil. Trans. 1804; and Thomson's Chemistry, v. 385. See Wild. p. 236.

termine decisively; the following experiment, however, should induce us to conclude that they do. If we take the stem of a common balsamine *, or of various other plants, and cut it horizontally at its lower end, and plunge it, so cut, into a decoction of Brazil wood, or any other coloured fluid, we shall perceive that the arteries or adducent vessels, as also the lacteals, will become filled or injected by an absorption of the coloured liquor; but that the veins, or reducent vessels, will not become filled; of course evincing an obstacle, in this direction, to the ascent of the coloured fluid. But if we invert the stem, and in like manner cut horizontally the extremity which till now was uppermost, and plunge it so cut into the same fluid, we shall then perceive that the veins will become injected, or suffer the fluid to ascend, but that the arteries will not: proving clearly the same kind of obstacle in the course of the arteries in this direction, which was proved to exist in the veins in the opposite direction; and which reverse obstacles we can scarcely ascribe to any other cause than the existence of valves.†

By this double set of vessels, moreover, pos-

* Impatiens *balsamina*.—This is the plant recommended by M. Wildenow for this purpose, as affording the clearest results.

† Yet Hales and Duhamel seem to have shown, that in the sap-vessels no valves exist; and that branches imbibe moisture nearly equally at either end. See Thomson's Chemistry, v. 385; an assertion, however, opposed by various facts. See also Smith's Introd. p. 57. 60.

sessed of an opposite power, and acting in an opposite direction, the one to convey the sap or vegetable blood forwards, and the other to bring it backwards, we are able very sufficiently to establish the phænomenon of a circulatory system; and, according to several of the experiments of M. Wildenow, it seems probable that this circulatory system is maintained by the projectile force of a regular and alternate contraction and dilatation of the vegetable vessels. Yet the great minuteness of these vessels must ever render it extremely difficult to obtain any thing like absolute certainty upon this subject. Even in the most perfectly established circulatory systems of animals, in man himself, it is not once in five hundred instances that we are able to acquire any manifest proof of such a fact: we are positive of the existence of an alternating systole and diastole in the heart, from the pulsation given to the larger arteries when pressed upon; but no degree of pressure produces any such pulsation in the minuter arteries, at least, in a healthy state; yet we have full reason to believe that the same action of the heart extends to the minutest as to the largest arteries. How much less, then, ought we to expect any full demonstration of this point in the vessels of vegetables, in every instance so much more minute than those of the more perfect animals, and seldom exceeding, as I have already observed, a three thousandth part of an inch in diameter!

It becomes me, however, to confess, that no

experiments which have hitherto been made have detected the existence of either motific or sensific fibres themselves in vegetables, although very high degrees of galvanic electricity have for this purpose been applied to the most irritable of them, as the dionæa *muscipula*, or Venus fly-trap; oxalis *sensitiva*; different species of drosera, or sun-dew; acacias of various kinds, and other mimosas; and especially the mimosa *pudica*, and *sensitiva*, the common sensitive plants of our green-houses. Humboldt has uniformly failed; Rafn appears to have succeeded in one or two instances, but his general want of success prevents us from being able to lay any weight on the single case or two in which he seems to have been more fortunate.

It should be observed, that the matter of fibrine, or the principle of the muscular fibre, formerly supposed to exist exclusively in animal substances, has lately been detected by M. Vauquelin in vegetables also. Dr. Hales cut off the stems of vines in the spring, and by fixing tubes on the stumps, found that the sap rose in many instances to the height of thirty-five feet. Tubes have been fixed to the large arteries of animals, as near as possible to the heart, in which the blood did not rise higher than nine feet.

It has long been admitted by botanists in general, that the thorns of plants are abortive branches; the scales of buds have, in like manner, been regarded as transformed leaves; and it has lately been conjectured by M. De Candolle, that

their petals are not special organs, but stamens in an abortive or transformed state.*

Plants are also possessed of cutaneous secernents or perspiratory vessels; and in many plants the quantity of fluid thrown off by this emunctory is very considerable. Keil, by a very accurate set of experiments, ascertained that in his own person he perspired 31 ounces in twenty-four hours. Hales, by experiments equally accurate, determined that a sun-flower, of the weight of three pounds only, throws off 22 ounces in the same period of time, or nearly half its own weight. To support this enormous expenditure it is necessary that plants should be supplied with a much larger proportion of nutriment than animals; and such is actually the fact. Keil ate and drank 4 lb. 10 oz. in the twenty-four hours. Seventeen times more nourishment was taken in from the roots of the sunflower than was taken in by the man.

Plants, nevertheless, do not appear to have the smallest basis for sensation, admitting that sensation is the result of a nervous system; and we are not acquainted with any other source from which it can proceed: notwithstanding that Percival and Darwin, as already observed, have not only endowed them with sensation, but with consciousness also; and the latter, indeed, with a brain, and the various passions and some of the senses to which this organ gives birth.†

* Mem. de la Societé d'Arcueil, tom. iii.

† Wildenow, Princip. of Botany, § 226.

Yet though the vessels of plants do not appear to possess any muscular fibres, we have evident proofs of the existence of a contractile and irritable power from some other principle; and a variety of facts concur in making it highly probable that it is by the exercise of such a principle that the different fluids are propelled through their respective vessels: nor is there any other method by which such propulsion can be reasonably accounted for. Grew ascribed the ascent of the sap to its levity, as though acting with the force of a vapour: Malpighi, to an alternate contraction and dilation of the air contained in what he erroneously conceived to be air-vessels: Perrault, to fermentation: Hales and Tournefort, to capillary attraction: not one of which theories, however, will better explain the fact than another, as Dr. Thomson has ably established; as he has also the probability of a contractile power in the different sets of vessels distributed so wonderfully over the vegetable frame.*

That a contractile power may exist independently of muscular fibres, we have abundant proofs even in the animal system itself. We see it in the human cutis or skin, which, though totally destitute of such fibres, is almost for ever contracting or relaxing upon the application of a variety of other powers; powers external and internal, and totally different in their mode of operation. Thus, austere preparations and se-

* Syst of Chem. vol. v. p. 388. 1807.

vere degrees of cold contract it very sensibly: heat, on the contrary, and oleaginous preparations, as sensibly relax it. The passions of the mind exercise a still more powerful effect over it: for while it becomes corrugated by fear and horror, it is smoothed and lubricated by pleasure, and violently agitated and convulsed by rage or anger.

Yet, could it even be proved that the vessels of plants are incapable of being made to contract by any power whatever, still should we have no great difficulty in conceiving a circulatory system in animals or vegetables without any such cause, while we reflect that one half of the circulation of the blood in man himself is accomplished without such a contrivance; and this, too, the more difficult half, since the veins, through the greater extent of their course, have to oppose the attraction of gravitation instead of being able to take advantage of it. It is in the present day, however, a well-known fact, and has been sufficiently ascertained by the late Dr. Parry of Bath, and on the Continent by Professor Dollinger, that the contractile power of the muscular fibres is not called into action even by the arteries in the course of the ordinary circulation of the blood, since, as we shall have occasion to observe, no increase of size or change of bulk of any kind takes place in arteries either in the contraction or dilatation of the heart's ventricles in a state of health, unless where they are

pressed upon by the finger or some other cause of resistance.

In what part of a plant the vital principle chiefly exists, or to what quarter it retires during the winter, we know not; but we are just as ignorant in respect to animal life. In both it operates towards every point; it consists in the whole, and resides in the whole; and its proof of existence is drawn from its exercising almost every one of its functions and effecting its combinations in direct opposition to the laws of chemical affinity, which would otherwise as much control it as they control the mineral world, and which constantly assume an authority as soon as ever the vegetable is dead. Hence the plant thrives and increases in its bulk; puts forth annually a new progeny of buds, and becomes clothed with a beautiful foliage of lungs (every leaf being a distinct lung in itself*) for the respiration of the rising brood; and with an harmonious circle of action, that can never be too much admired, furnishes a perpetual supply of nutriment, in every diversified form, for the growth and perfection of animal life; while it receives in rich abundance, from the waste and diminution, and even decomposition of the same, the means of new births, new buds, and new harvests.

* On the leafing of trees, there is a curious and valuable paper in the Swedish Amœnitates Academicæ, vol. iii. art. 46. by H. Barck, 1753, entitled Vernatio Arborum.

In fine, every thing is formed for every thing; and subsists by the kind intercourse of giving and receiving benefits. The electric fire that so alarms us by its thunder, and by the awful effects of its flash, purifies the stagnant atmosphere above us; and fuses, when it rushes beneath us, a thousand mineral veins into metals of incalculable utility. New islands are perpetually rising from the unfathomable gulfs of the ocean, and enlarging the boundaries of organized life; sometimes thrown up, all of a sudden, by the dread agency of volcanoes, and sometimes reared imperceptibly by the busy efforts of corals and madrapores. Liverworts and mosses first cover the bare and rugged surface, when not a vegetable of any other kind is capable of subsisting there. They flourish, bear fruit, and decay, and the mould they produce forms an appropriate bed for higher orders of plant-seeds, which are floating on the wings of the breeze, or swimming on the billows of the deep. Birds next alight on the new-formed rock, and sow, with interest, the seeds of the berries, or the eggs of the worms and insects on which they have fed, and which pass through them without injury; and an occasional swell of the sea floats into the rising island a mixt mass of sand, shells, drifted sea-weed, skins of the casuarina, and shells of the cocoa-nut. Thus the vegetable mould becomes enriched with animal materials; and the whole surface is progressively covered with herbage, shaded by forests of cocoa and

other trees, and rendered a proper habitation for man and the domestic animals that attend upon him.

The tide that makes a desolating inroad on one side of a coast, throws up vast masses of sand on the opposite: the lygeum, or sea-matweed, that will grow on no other soil, thrives here and fixes it, and prevents it from being washed back or blown away; to which the lime-grass *, couch-grass †, sand-reed ‡, and various species of willow, lend their aid. Thus fresh lands are formed, fresh banks upraised, and the boisterous sea repelled by its own agency.

Frosts and suns, water and air, equally promote fructification in their respective ways; and the termes, or white ant, the mole, the hampster, and the earth-worm, break up the ground or delve into it, that it may enjoy their salubrious influences. In like manner, they are equally the ministers of putrefaction and decomposition; and liverworts and fungusses, the ant and the beetle, the dew-worm, the ship-worm, and the wood-pecker, contribute to the general effect, and soon reduce the trunks of the stoutest oaks, if lying waste and unemployed, to their elementary principles, so as to form a productive mould for successive progenies of animal or vegetable existence. Such is the simple but beautiful circle of nature. Every thing lives, flourishes, and decays: every thing dies, but nothing is lost: for the great

* Elymus *arenarius*. † Triticum *repens*.
‡ Arundo *arenaria*.

principle of life only changes its form, and the destruction of one generation is the vivification of the next.* Hence, the Hindu mythologists, with a force and elegance peculiarly striking, and which are no where to be paralleled in the theogonies of Greece and Rome, describe the Supreme Being, whom they denominate Brahm, as forming and regulating the universe through the agency of a triad of inferior gods, each of whom contributes equally to the general result, under the names of Brahma, Visnu, and Iswara; or the generating power, the preserving or consummating power, and the decomposing power. And hence the Christian philosopher, with a simplicity as much more sublime than the Hindu's, as it is more veracious, exclaims, on contemplating the regular confusion, the intricate harmony, of the scenes that rise before him —

> These, as they change, Almighty Father! these
> Are but the varied God. The rolling year
> Is full of Thee.

* See upon this subject the Swedish Amœnitates Academicæ, vol. v. art. 80. by J. H. Hagen, 1757, entitled Natura Pelagi.

LECTURE IX.

ON THE GENERAL ANALOGY OF VEGETABLE AND ANIMAL LIFE.

(The subject continued.)

THE perfection of an art consists in the employment of a comprehensive system of laws, commensurate to every purpose within its scope, but concealed from the eye of the spectator; and in the production of effects that seem to flow forth spontaneously, as though uncontrolled by their influence, and which are equally excellent, whether regarded individually, or in reference to the proposed result.

Such is the great art of nature: and he who would study it with success must, as far as he is able, trace out its various laws, and reduce them to general principles, and collect its separate phænomena, and digest them into general classes. This, in many instances, we are able to do; and in such cases we obtain a tolerable insight into the nature of things. But so vast, so unbounded is the theatre before us, so complicated is its machinery, and so closely does one fact follow up and press upon another, that we are often bewildered and lost in the mighty maze, and are incapable of determining the laws by which

it is regulated, or of arranging the phænomena of which it is composed.

The zoologist, in order to assist his enquiries, divides the whole animal creation into six general heads or classes: as those of mammals, birds, amphibials, fishes, insects, and worms. Each of these classes he subdivides into orders; of each of his orders he makes a distinct section for a multitude of kinds or genera; and each of his kinds becomes a still more subordinate section for the species or individuals of which the separate kinds consist. But he is perpetually finding, not only that many cases in each of his inferior divisions are so equally allied to other divisions that he knows not how to arrange them, but that even his classes or first divisions themselves labour under the same difficulty; since he occasionally meets with animals that by the peculiarity of their construction seem equally to defy all artificial method and all natural order. Thus the myxine *glutinosa*, which by Linnéus was regarded and ranked as a worm, has been introduced by Bloch into the class of fishes, and is now known by the name of gastrobranchus *cæcus*, or hag-fish. The siren *lacertina*, which was at first contemplated by Linnéus as an amphibious animal of a peculiar genus, was afterwards declared by Camper and Gmelin to be a fish, approaching the nature of an eel, and was arranged accordingly. It has since, however, been restored from the class of fishes to that of amphibials, and is in the pre-

sent day believed by various zoologists to be nothing more than a variety of the lizard. And thus the hippopotamus, the tapir, and the swine, which by Linnéus were ranked in the fifth order of mammals with the horse, are arranged by Cuvier with the rhinoceros and the sokostyro, that have hitherto formed a part of the second order.

The eel, in its general habits and appearance, has a near similitude to the serpent; many of its species live out of the water as well as in it; and, like the serpent, hunt for worms, snails, and other food, over meadows and marshes.

The platypus *anatinus*, or duck-bill, (the ornithorhyncus *paradoxus* of Blumenbach,) one of the many wonders of New South Wales, unites in its form and habits the three classes of birds, quadrupeds, and amphibials. Its feet, which are four, are those of a quadruped; but each of them is palmate or webbed, like a wild-fowl's; and instead of lips it has the precise bill of a shoveler or other broad-billed water bird; while its body is covered with a fur exactly resembling an otter's. Yet it lives, like a lizard, chiefly in the water, digs and burrows under the banks of rivers, and feeds on aquatic plants and aquatic animals. The viverra or weasel, in several of its species, approaches the monkey and squirrel tribes; is playful, a good mimic, and possesses a prehensile tail. The flying squirrel, the flying lizard, or draco *volans*, and especially the bat, approach in their volant endowment the buoy-

ancy of birds, and are able to fly by winged membranes instead of by feathers. The exocetus *volitans*, or flying-fish, and several other fishes, derive a similar power from their long pectoral fins; while the troctilus, or humming-bird, unites the class of birds with that of insects. It is in one of its species, t. *minimus*, the least of the feathered tribes; feeds, like insects, on the nectar of flowers alone, and like the bee, or butterfly, collects it while on the wing, fluttering from flower to flower, and all the while humming its simple accent of pleasure. Its tongue, like that of many insects, is missile. When taken it expires instantly; and after death, on account of its diminutive size, the elegance of its shape, and the beauty of its plumage, it is worn by the Indian ladies as an ear-ring.

Such being the perplexity and seeming confusion that extend through the whole chain of animal life, it is not to be wondered at that we should at times meet with a similar embarrassment in distinguishing between animal life and plants, and between plants and minerals. I gave a cursory glance at this subject in our last lecture, and especially in regard to that extraordinary division of organized substances which, for want of a better term, we continue to denominate zoophytes; many of which, as, for example, various species of the alcyony and madrepore, bear a striking resemblance to crystals, and other mineral concretions; while great numbers of them, and particularly the corals, corallines,

and some other species of alcyony, as the sea-fig, sea-quince, pudding-weed, and above all the stone-lily, (which last, however, is now only found in a petrified state,) have the nearest possible approach to a vegetable appearance. Whence, as I have already observed, amongst the earlier naturalists, who expressly directed their attention to these substances, some regarded them as minerals, and others as vegetables; and it is not till of late years, only, indeed, since it has been ascertained that the chemical elements they give forth on decomposition are of an animal nature, that they have been admitted into the animal kingdom.

Among plants, in like manner, we often meet with instances of individual species that are equally doubtful, not only as to what kind, order, or class of vegetable existence they belong, but even as to their being of a vegetable nature of any kind, till their growth, their habits, and their composition are minutely examined into. But independently of these individual cases, we also perceive, in the general principle of action in animal life, that the more it is investigated, the more it is calculated to excite our astonishment, and to indicate to us, so far as relates to the SUBORDINATE POWERS of the animal frame, the application of one common system to both, and to demonstrate one common derivation, from one common and Almighty Cause. Having, therefore, in our last lecture, submitted to your attention a brief

outline of the structure of plants, I shall now proceed to point out a few of these general resemblances, and shall endeavour to select those which are either most curious or most prominent.*

Plants, then, like animals, are produced by ordinary generation; and though we meet with various instances of production by the generation of buds and bulbs, or of slips and offsets, the parallelism, instead of being hereby diminished, is only drawn the closer; for we meet with just as many instances of the same varieties of propagation among animals. Thus the hydra, or polype, as it is more generally called, the asterias, and several species of the leech, as the hirudo *viridis*, for example, are uniformly propagated by lateral sections, or pullulating slips or offsets †; while almost every genus of zoophytic worms is only capable of increase by buds, bulbs, or layers; and some of these animals, like the house-leek and various grasses, by spontaneous separation. In effect, most of the kinds now referred to, whether animals or vegetables, may be regarded less as single individuals than as assem-

* Consult also Mr. Kuight's article, Phil. Trans. 1810, part ii. p. 179—181.

† Thus Aristotle, upon a subject which is generally supposed to be of modern discovery, Ὥσπερ γὰρ τα φυτὰ καὶ ταῦτα (scilicet) ἔντομα διαιρούμενα δυνατοί ζῆν. "For, like plants, such insects also maintain life, after slips or cuttings." *Hist. Anim.* lib. iv. ch. 8.

See a variety of other curious instances in the author's translation of Lucretius, note to b. ii. ver. 880.

blages or congeries of individuals; for in most of them every part exists distinctly of every other part, and is often a miniature of the general form. The various branches of a tree offer a similar example, and present a striking contrast with the various branches of a perfect animal. In the latter every distinct part contributes to one perfect whole: the arm of a man has no heart, no lungs, no stomach; but the branch of a tree has a complete system of organs to itself, and is hence capable in many cases of existing by itself, and producing buds, layers, and other kinds of offspring, when separated from the trunk. The different parts of the polype are equally independent, and are hence equally capable of a separate increase. It is owing to this principle we are able to graft and bud: and M. Trembley having applied the same kind of operation to the animals we are now speaking of, found that, by numerous grafts of different kinds upon each other, he was enabled to produce monsters as wild and extravagant as the most visionary poet or fabulist ever dreamed of.

The blood of plants, like that of animals, instead of being simple is compound, and consists of a great multitude of compacter corpuscles, globules for the most part, but not always globules, floating in a looser and almost diaphanous fluid. From this common current of vitality, plants, like animals, secrete a variety of substances of different, and frequently of opposite powers and qualities,—substances nutritive,

medicinal, or destructive. And, as in animal life, so also in vegetable, it is often observed that the very same tribe, or even individual, that in some of its organs secretes a wholesome aliment, in other organs secretes a deadly poison. As the viper pours into the reservoir situated at the bottom of his hollow tusk a fluid fatal to other animals, while in the general substance of his body he offers us not only a healthful nutriment, but, in some sort, an antidote for the venom of his jaw: so the jatropha *Manihot*, or Indian cassava, secretes a juice or oil extremely poisonous in its root, while its leaves are regarded as a common esculent in the country, and are eaten like spinach-leaves among ourselves; though the root, when deprived, by exposure to heat, of this poisonous and volatile oil, is one of the most valuable foods in the world, and gives bread to the natives, and tapioca as an article of commerce. Its starch is like that of the finest wheat-flour, and combined with potatoes and sugar, yields a very excellent cyder and perry, according to the proportions employed. In like manner, while the bark of the cinnamon tree (laurus *Cinnamomum*) is exquisitely fragrant, the smell of the flowers is highly offensive, and by most persons is compared to that of newly-sawn bones, — by St. Pierre to that of human excrement.* So the cascarilla bark and castor oil are

* Mr. Marshall's account delivered to the Royal Society. See Thomson s Annals, Sept. p. 242.

obtained from plants poisonous in some part or other.

The amyris, in one of its species offers the balm-of-Gilead tree; in another, the gum-elemi tree; and in a third*, the poison-ash, that secretes a liquid gum as black as ink. It is from a fourth species of this genus, I will just observe as I pass along, in order the more completely to familiarize it to us, that we obtain that beautiful plant which, under the name of rose-wood †, is now so great a favourite in our drawing-rooms.

The acacia *nilotica* ‡, or gum-Arabic tree, is a rich instance in proof of the same observation. Its root throws forth a fluid that smells as offensively as asafœtida; the juice of its stem is severely sour and astringent; the secernents of its cutis exude a sweet, saccharine, nutritive gum, the common gum-Arabic of the shops, and its flowers diffuse a highly fragrant and regaling odour. So the Arenga palm produces sugar, an excellent sago, and a poisonous juice that even irritates the skin.

But perhaps the laurus, as a genus, offers us the most extensive variety of substances of different qualities. This elegant plant, in one of its species, gives us the cinnamon tree §; in another, the cassia, or wild cinnamon ‖; in a third, the camphor tree ¶; in a fourth, the

* A. *toxifera*. † A. *balsamifera*. ‡ Mimosa *nilotica*, Linn.

§ L. *Cinnamomum*. ‖ L. *Cassia*. ¶ L. *Camphora*.

alligator-pear *; in a fifth, the sassafras †; in a sixth, a sort of gum-Benjamin ‡, though not the real gum-Benjamin, which is a styrax; while in a seventh, the l. *caustica*, it exhibits a tree with a sap as poisonous as that of the manchineel.

And truly extraordinary is it, and highly worthy of notice, that various plants, or juices of plants, which are fatally poisonous to some animals, may not only be eaten with impunity by others, but will afford them a sound and wholesome nutriment. How numerous are the insect tribes that feed and fatten on all the species of euphorbia, or noxious spurge! The dhanesa, or Indian buceros, feeds to excess on the nux vomica; the land-crab § on the berries of the hippomane or manchineel-tree, and the loxia (grossbeak) of the Bahamas on the fruit of the amyris *toxifera*, or poison-ash. ‖ The leaves of

* L. *Persea.* † L. *Sassafras.*
‡ L. *Benzoin.* § Cancer *Ruricola.*

‖ See on this subject the following curious papers in the Swedish Amœnitates Academicæ, vol. ii. art. 25. par Sueisens, by N. L. Hesselgren. The same subject continued by G. P. Tengmalon, Amœn. Acad. vol. x. art. x. Usus Historiæ Naturalis, by M. Aphonin, art. 147. Id. in respect to birds, entitled Esca Avium domesticarum, by P. Holmbergen, p. 481. art. 163.

It is also well worthy of remark, that various herbaceous plants which spring up among others that are esculent, yet are rejected by cattle when offered alone, give a higher relish and even salubrity to the fodder with which they are intermixed. This, as Sir J. E. Smith has admirably observed, is particularly the case with the grasses. " As man cannot live on tasteless

of the kalmia *latifolia* are feasted on by the deer and the round-horned elk, but are mortally poisonous to sheep, to horned cattle, to horses, and to man. The bee extracts honey without injury from its nectary, but the adventurer who partakes of that honey after it is deposited in the hive-cells falls a victim to his repast.

There are some tribes of animals that exfoliate their cuticle annually, such as grass-hoppers, spiders, several species of crabs, and serpents. Among vegetables we meet with a similar variation from the common rule, in the shrubby cinque-foil*, indigenous to Yorkshire, and the plane-tree of the West Indies †, which most readers know sends forth every spring new colonies by means of runners, as we usually denominate them, in every direction, that, shortly after they have obtained a settlement for themselves, break off all connection with the parent stock.

Among animals, some are locomotive or migratory, and others stationary or permanent; the same variety is to be traced among vegetables. Unquestionably the greater number of animals are of the migratory kind, yet in every order of

unmixed flour alone, so neither can cattle in general be supported by mere grass, without the addition of various plants, in themselves too acid, bitter, salt, or narcotic, to be eaten unmixed. Spices and a portion of animal food supply us with the requisite stimulus or additional nutriment, as the ranunculus tribes, and many others, season the pasturage and fodder of cattle." *Engl. Flora*, vol. i.

* Potentilla *fruticosa*. † Platanus *occidentalis*.

worms we meet with some instances that naturally appertain to the latter, while almost every genus and species of the zoophytic order, its millepores, madrepores, tubipores, gorgonias, isises, corallines, and sponges, can only be included under it. Plants, on the contrary, are for the most part stationary, yet there are many that are fairly entitled to be regarded as locomotive or migratory. The natural order SENTICOSÆ, the ICOSANDRIA POLYGYNIA of the sexual system, offers us a variety of instances, of which the *fragaria* or strawberry genus may be selected as a familiar example. The palmate, the testicular, and the premorse rooted tribes afford us similar proofs:—many of these grow from a new bulb, or knob, or radicle, while the old root, of whatever description it may be, dies away; in consequence of which we can only conclude that the vital principle of the plant has quitted an old, dilapidated, and ruinous mansion, to take possession of a new one. Insomuch that were a person, on the point of travelling to the East Indies, to plant the root of an orchis *, or a scabious †, in a particular spot in his garden, and to search for it in the same spot on his return home, he would be in no small degree disappointed; and if he were to remain abroad long, he must carry his pursuit to half an acre's

* Orchis *morio*, or *latifolia*.

† Scabiosa *succisa*, or devil's bit.

distance, for thus far would some of these roots perhaps have travelled in a few years.

The male valisneria sails from shore to shore over the water in pursuit of his female. And a multitude of sea-plants float through the ocean, and having plenty of food wherever they go, send out no roots in order to search for it.

Plants, like animals, have a wonderful power of maintaining their proper temperature, whatever be the temperature of the atmosphere that surrounds them; and hence occasionally of raising the thermometer, and occasionally of depressing it. Like animals, too, they are found to exist in most astonishing degrees of heat and cold, and to accommodate themselves accordingly. Wherever the interest or curiosity of man has led him into climates of the highest northern latitudes; wherever he has been able to exist himself, or to trace a vestige of animal being around him; there, too, has he beheld plants of an exquisite beauty and perfection; perfuming, in many instances, the dead and silent atmosphere with their fragrances, and embellishing the barren scenery with their corols.

It is said that animals of a certain character, the cold-blooded and amphibious, have a stronger tenacity to life than vegetables of any kind. But the assertion seems to have been hazarded too precipitately; for, admitting that the common water-newt * has been occasionally found im-

* Lacerta *aquatica*,

bedded in large masses of ice, perfectly torpid and apparently frozen; and that the common eel *, when equally frozen and torpified, is capable of being conveyed a thousand miles up the country, as from St. Petersburg, for example, to Moscow, in which country, we are told, it is a common practice thus to convey it; and that both, on being carefully thawed, may be restored to as full a possession of health and activity as ever; yet the torpitude hereby induced can only be compared to that of deciduous plants in the winter months; during which season we all know that, if proper care be exercised, they may be removed to any distance whatever without the smallest inconvenience.

Plants, again, are capable of existing in very high degrees of heat. M. Sonnerat found the vitex *Agnus castus*, and two species of aspalathus, on the banks of a thermal rivulet in the island of Lucon, the heat of which raised the thermometer to 174° of Fahrenheit, and so near the water that its roots swept into it. Around the borders of a volcano in the isle of Tanna, where the thermometer stood at 210°, Mr. Forster found a variety of flowers flourishing in the highest state of perfection; and confervas, and other water-plants, are by no means unfrequently traced in the boiling springs of Italy, raising the thermometer to 212° or the boiling point.

* Muræna *Anguilla*.

Animals are capable of enduring a heat quite as extreme. Air has often been breathed by the human species with impunity at 264°. Tillet mentions its having been respired at 300°; the Royal Academy asserts at 307°, or 130° Reaumur, in an oven, for the space of ten minutes*; and Morantin gives a case at 325° Fahr., and that for a space of five minutes. Even in the denser medium of water, animals of various kinds, and especially fishes, have been occasionally traced alive and in health in very high temperatures. Thus Dr. Clarke asserts, that in one of the tepid springs of Bonarbashy, situated near the Scamander, or Mender as it is now called, notwithstanding the thermometer was raised to 62° Fahr., fishes were seen sporting in the reservoir. †

So in the thermal springs of Bahia in Brazil many small fishes are seen swimming in a rivulet that raises the thermometer to 88°, the temperature of the air being only 77½°. Sonnerat, however, found fishes existing in a hot spring at the Manillas at 158° Fahr. ‡: and M. Humboldt and M. Bonpland, in travelling through the province of Quito in South America, perceived other fishes thrown up alive, and apparently in health, from the bottom of a volcano, in the course of its explosions, along with water and heated

* Hist. de l'Acad. Royale des Sciences, 1764, p. 186. h. 16.

† Travels, part II. Greece, Egypt, and the Holy Land, p. 111. 4to. ed.

‡ He graduates by Reaumur's thermometer, and calculates the heat upon this at 69°.

vapour that raised the thermometer to 210°, being only two degrees short of the boiling point. *

In reality, without wandering from our own country, we may at times meet with a variety of other phænomena perfectly consonant in their nature, and altogether as extraordinary, if we only attend to them as they rise before us. Thus the eggs of the musca *vomitoria*, our common flesh-fly, or blow-fly, are often deposited in the heat of summer upon putrescent meat, and broiled with such meat over a gridiron in the form of steaks, in a heat not merely of 212°, but of three or four times 212°; and yet, instead of being hereby destroyed, we sometimes find them quickened by this very exposure into their larve or grub state. And although I am ready to allow that, in the simple form of seeds or eggs, plants or animals may be expected to sustain a far higher degree of heat or cold with impunity, than in their subsequent and more perfect state; yet it cannot appear more extraordinary that in such perfect state they should be able to resist a heat of 210° or 212°, than that in the state of seeds or eggs they should be able to exist in, and to derive benefit from, a heat three or four times as excessive.

In the vegetable world we meet with other peculiarities quite as singular, and which gives them an approach to the mineral kingdom: we have already observed that some of them, and

* Recueil d'Observations de Zoologie et d'Anatomie comparée.

especially among the algæ and the mosses, are nearly or altogether incombustible, as the byssus *asbestos*, which, on being thrown into the fire, instead of burning, is converted into glass ; and the fontinalis *antipyretica*, a plant indigenous to the Highlands, but more frequent in Scandinavia, where from its difficulty of combustion it is used by the poor as a lining for their chimnies to prevent them from catching fire.

Animals are often contemplated under the three divisions of terrestrial, aquatic, and aërial. Plants may be contemplated in the same manner. Among animals it is probable that the largest number consists of the first division ; yet from the great variety of submarine genera that are known, and from nearly an equal variety, perhaps, that are not known, this is uncertain. Amongst vegetables, however, it is highly probable that the largest number belongs to the submarine section, if we may judge from the almost countless species of fuci and other equally prolific tribes of an aqueous and subaqueous origin, and the incalculable individuals that appertain to each species; and more especially if we take into consideration the greater equality of temperature which must necessarily exist in the submarine hills and valleys.

Many animals are amphibious, or capable of preserving life in either element; the vegetable world is not without instances of a similar power. The algæ, and especially in the ulva and fucus tribes, offer us a multitude of examples. The

juncus, or rush, in many of its species, is an amphibious plant; so, too, is the oryza or rice-plant. In other words, all these will flourish entirely covered with water, or with their roots alone shooting into a moist soil.

Animals of various kinds are aërial: perhaps the term is not used with strict correctness. It will, at least, apply with more correctness to plants. All the most succulent plants of hot climates are of this description: such are several of the palms and of the canes; and the greater number of plants that embellish the arid Karro fields of the Cape of Good Hope.* Succulent as they are, these will only grow in soils or sands so sere and adust that no moisture can be extracted from them, and are even destroyed by a full supply of wet or by a rainy season. The Solandra *grandiflora*, a Jamaica shrub, was long propagated in our own stoves by cuttings, which, though freely watered, could never be made to produce any signs of fructification, notwithstanding that the cuttings grew several feet in length every season. By accident a pot with young cuttings was mislaid and forgotten in the Kew garden, and had no water given it; it was hereby reduced to its healthy aridity, and every extremity produced a flower.†

* The only rain that waters this tract is that which falls for a few weeks in the winter; during the hot and fertile months there is no rain whatever.

† Smith's Introduction to Botany &c., p. 141.

And hence it is an opinion common to many of the ablest physiologists of the present day, that these derive the whole of their nutriment from the surrounding atmosphere; and that the only advantage which they acquire from thrusting their roots into such strata is that of obtaining an erect position. There are some quadrupeds that appear to derive nutriment in the same manner. Thus the bradypus *tridactylus*, or sloth, never drinks, imbibes by its cutaneous absorbents, and trembles at the feeling of rain; and, in common with the bird tribes, has only one ultimate or excrementary duct; while the olive cavy* avoids water of every kind almost as pertinaciously, as does also the ostrich, which is in consequence said by the Arabs never to drink. And yet these are animals almost as succulent as any we are acquainted with.

But however true this may be with regard to animals, we have manifest proofs that vegetables of certain tribes and descriptions are altogether supported by the atmosphere that surrounds them; for, important as is the organ of a root to plants in general, there are several which have no root whatever, and can derive nutriment in no other way. The water-caltrop † is an instance directly in point. The seed of this plant has no

* Cavia *Acuschy*. This is the more extraordinary, because the c. *Cobaya*, or Guinea-pig, drinks freely; and the c. *Capybara*, or river cavy, is fond of swimming and diving.

† Trapa *natans*.

rootel, and consequently can never, in the first instance, become rooted. From the horned nut or pericarp of the seed, as it lies in water, which is its natural element, shoots forth a long plumule perpendicularly towards the surface of the stream; during the ascent of which a variety of capillary branched leaves shoot forth from the sides of the plumule, some of which bend downward, and fix the whole plant to the bottom by penetrating into the soil below the stream; the leaves alone in this late stage of germination acting the part of a root, and giving maturity to the still unfinished plant. The cactus genus, in some of its very numerous species, offers us an example of similar evolution; and especially in the opuntia tribe, or that which embraces the prickly pears or Indian figs of our green-houses, of which the cochineal plant* is one form. Of these, several grow by the mere introduction of one of their thick fleshy leaves into a soil of almost any kind that is sufficiently dry; they obtain an erect position, but never root, or shoot forth radicles: and hence almost the whole of their moisture must necessarily be derived from the surrounding atmosphere.

Perhaps one half of the fuci have no root whatever: many of them, indeed, consist of vesicles or vesicular bulbs alone, sessile upon the matrix of some stone or shell that supports them, and propagate their kinds by offsets, without any

* Cactus *coccinellifer*.

other vegetable organs. The seeds of the fucus *prolifer* sometimes evolve nothing but a leaf; the plant being propagated also by leaf upon leaf, either forked or elliptic, without root.

The aphyteia *hydnora* is a curious instance in point. This plant is equally destitute of leaves, stem, and root; and consists alone of a sessile, coriaceous, and succulent flower, eaten as a luxury by the Hottentots, and parasitic to the roots of the euphorbia *Mauritanica*; flower propagating flower from generation to generation.

But perhaps the plant most decisive upon this subject is the aërial *epidendrum* *, first, if I mistake not, described by that excellent Portuguese phytologist Loureiro, and denominated *aërial* from its very extraordinary properties. This is a native of Java and the East Indies beyond the Ganges; and, in the latter region, it is no uncommon thing for the inhabitants to pluck it up, on account of the elegance of its leaves, the beauty of its flower, and the exquisite odour it diffuses, and to suspend it by a silken cord from the ceilings of their rooms; where, from year to year, it continues to put forth new leaves, new blossoms, and new fragrance, excited alone to new life and action by the stimulus of the surrounding atmosphere.

That stimulus is oxygene; ammonia is a good stimulus, but oxygene possesses far superior powers, and hence without some portion of

* Epidendrum *flos aeris*.

oxygene few plants can ever be made to germinate. Hence, too, the use of cow-dung and other animal recrements, which consist of muriatic acid and ammonia: while in fat, oil, and other fluids, that contain little or no oxygene, and consist altogether, or nearly so, of hydrogene and carbone, seeds may be confined for ages without exhibiting any germination whatever. And hence, again, and the fact deserves to be extensively known, however torpid a seed may be, and destitute of all power to vegetate in any other substance, if steeped in a diluted solution of oxygenated muriatic acid, at a temperature of about 46° or 48° of Fahrenheit, provided it still possess its principle of vitality, it will germinate in a few hours. And if, after this, it be planted, as it ought to be, in its appropriate soil, it will grow with as much speed and vigour as if it had evinced no torpitude whatever.

I have said that few plants can be made to germinate when the oxygene is small in quantity, and the hydrogene abundant: and I have made the limitation, because aquatic plants, and such as grow in marshes, and other moist places, are remarkable, not only for parting with a large quantity of oxygene gass, but also for absorbing hydrogene gass freely; and are hence peculiarly calculated for purifying the regions in which they flourish, and in some sort for correcting the mischief that flows from the decomposition of the dead vegetable and animal materials that

is perpetually taking place in such situations, and loading the atmosphere with febrile and other miasms.

But the instances of resemblance between animal and vegetable physiology are innumerable. Some plants, like a few of our birds, more of our insects, and almost all our forest beasts, appear to sleep through the day, and to awake and become active at night: while the greater number, like the greater number of animals, resign themselves to sleep at sun-set, and awake re-invigorated with the dawn. Like animals, they all feel the living power excited by small degrees of electricity, but destroyed by severe shocks; and like animals, too, they differ in a very extraordinary degree in the duration of many of their species. Some tribes of boletus unfold themselves in a few hours, like the ephemera and hemerobius tribes (May-fly and Spring-fly), and as speedily decay. Several of the fungi live only a few days; others weeks or months. Annual plants, like the greater part of our insects, live three, four, or even eight months. Biennial plants, like the longer-lived insects, and most of our shell-fishes, continue alive sixteen, eighteen, or even twenty-four months. Many of the herbaceous plants continue only a few years, but more for a longer period, and imitate all the variety to be met with in the greater number of birds, quadrupeds, and fishes; while shrubs and trees are, for the most part, coequal with the age of man, and a few of them equal that allotted

to him in the earliest periods of the world. Of these last, the Adansonia *digitata*, or calabash tree, is perhaps one of the most extraordinary. Indigenous to the land of the patriarchs, and still outrivalling the patriarchal age, this stupendous tree, compared with which our own giant oak, in bulk as well as in years, is but an infant, seems to require not less than a thousand years to give it full vigour and maturity. Extending its enormous arms over the dry and barren soil from which it shoots naturally, it affords shelter to whole nations of barbarians, and n its pleasant subacid fruit administers an ample supply to their hunger.

Let it not, however, be imagined that, by pointing out such frequent instances of resemblance between animal and vegetable life, I mean to degrade the rank of animal being from its proper level; for it will be one of the chief objects of our subsequent studies to develope and delineate its multiform and characteristic superiorities. I am only tracing at present the common principle of vitality to its first outlines: I am endeavouring to unfold to you, in its simplest and rudest operations, that grand, and wonderful, and comprehensive system, which, though under different modifications, unquestionably controlling both plants and animals, from the first moment it begins to act infuses energy into the lifeless clod, draws forth form and beauty, and individual being, from unshapen matter, and stamps with organization and propensities the common

dust we tread upon. And if, in this its lowest scale of operation, — if, under the influence of these its simplest laws, and the mere powers (so far as we are able to trace them) of contractility and irritability, it be capable of producing effects thus striking, thus incomprehensible, what may we not expect when the outline is filled up and the system rendered complete? What may we not expect when we behold, superadded to the powers of contractility and irritability, those of sensation and voluntary motion? What, more especially, when to these are still further added the ennobling faculties of a rational and intelligent soul, — the nice organs of articulation and speech, — the eloquence of language, — the means of interchanging ideas, and of embodying, if I may so express myself, all the phænomena of the mind?

Such are the important subjects to which our subsequent studies are to be directed. In the meantime, from the remarks which have already been hazarded, we cannot, I think, but be struck with the two following sublime characters, which pre-eminently, indeed, distinguish all the works of nature: — a grand comprehensiveness of scheme, a simple but beautiful circle of action, by which every system is made to contribute to the well-being of every system, every part to the harmony and happiness of the whole; and a nice, and delicate, and ever-rising gradation from shapeless matter to form, from form to feeling, from feeling to intellect, from the clod

to the crystal, from the crystal to the plant, from the plant to the animal, from brutal life to man. Here, placed on the summit of this stupendous pyramid, lord of all around him, the only being through the whole range of the visible creation endowed with a power of contemplating and appreciating the magnificent scenery by which he is encompassed, and of adoring its Almighty Architect — at once the head, the heart, and the tongue of the whole — well, indeed, may he exult and rejoice! But let him rejoice with modesty. For, in the midst of this proud exaltation, it is possible that he forms but one of the lowest links in "the golden everlasting chain" of intelligence; that he stands on the mere threshold of the world of perception; and that there exists at least as wide a disproportion between the sublimest characters that ever were born of women, our Bacons, Newtons, and Lockes, our Aristotles, Des Cartes, and Eulers, and the humblest ranks of a loftier world, as there is between these highly-gifted mortals and the most unknowing of the animal creation. Yet MIND, thanks to its beneficent bestower! is itself immortal, and knowledge is eternally progressive; and hence man, too, if he improve the talents entrusted to him, as it is his duty to do, may yet hope, unblamed, to ascend hereafter as high above the present sphere of these celestial intelligences, as they are at present placed above the sphere of man. But these are speculations in some degree too sublime for us: the

moment we launch into them, that moment we become lost, and find it necessary to return with suitable modesty to our proper province, an examination of the world around us; where, with all the aids of which we can avail ourselves, we shall still find difficulties enough to try the wisdom of the wisest, and the patience of the most persevering.

LECTURE X.

ON THE PRINCIPLE OF LIFE, IRRITABILITY, AND MUSCULAR POWER.

We have distinguished organic from inorganic matter; and have characterised the former, among other differences, by its being actuated in every separate form by an internal principle, and possessed of parts mutually dependent and contributory to each other's functions. What then is this internal principle, — this wonderful and ever active power, which, in some sort or other, equally pervades animals and vegetables,— which extends from man to brutes, from brutes to zoophytes, from zoophytes to fucuses and confervas, the lowest tribes of the vegetable kingdom, whose general laws and phænomena constituted the subject of our last study, — this fleeting and evanescent energy, which, unseen by the eye, untracked by the understanding, is only known, like its great Author, by its effects; but which, like him too, wherever it winds its career, is perpetually diffusing around it life and health, and harmony and happiness?

I do not here enter into the consideration of a thinking or intelligent principle, or even a prin-

ciple of sensation, both which are altogether of distinct natures from the present, and to which I shall intreat your attention hereafter; but confine myself entirely to that inferior but energetic power upon which the identity and individuality of the being depends, and upon a failure of which the individual frame ceases, the organs lose their relative connexion, the laws of chemistry, which have hitherto been controlled by its superior authority, assume their action, and the whole system becomes decomposed and resolved into its primary elements.

The subject is, indeed, recondite, but it is deeply interesting: it has occupied the attention of the wisest and the best of mankind in all ages; and though, after the fruitless efforts with which such characters have hitherto pursued it, I have not the vanity to conceive that I shall be able to throw upon it any thing like perfect daylight, you will not, I presume, be displeased with my submitting to you a brief outline of some few of the speculations to which it has given birth, together with the conjectures it has excited in my own mind.

Of the innumerable theories that have been started upon this subject, the three following are those which are chiefly entitled to our attention. Life is the result of a general harmony or consent of action between the different organs of which the vital frame consists.—Life is a principle inherent in the blood.—Life is a gass, or aura, communicated to the system from without.

Each of these theories has to boast of a very high degree of antiquity; and each, after having had its day, and spent itself, has successively yielded to its rivals; and in its turn has re-appeared, under a different modification, in some subsequent age, and run through a new stage of popularity.

For THE SYSTEM OF HARMONY we are indebted to the inventive genius of Aristoxenus, a celebrated physician of Greece, who was at first a pupil of Lamptus of Erythræa, afterwards of Xenophylus the Pythagorean, and lastly of Aristotle. He was most excellently skilled in music, and is supposed to have given the name of HARMONY to his system from his attachment to this science. It is an ingenious and elegant dogma, and was at one time highly fashionable at Rome as well as at Athens; and is thus alluded to and explained by Lactantius: "As in musical instruments, an accord and assent of sounds, which musicians term HARMONY, is produced by the due tone of the strings; so in bodies, the faculty of perception proceeds from a connexion and vigour of the members and organs of the frame." *

To this theory there are two objections, either of which is fatal to it. The first is, that admitting the absolute necessity of the health or perfection of every separate part to the health or perfection of the whole, we are still as much

* v. 140.

in the dark as ever in respect to the principle by which this harmonious machine has been developed, and is kept in perpetual play. The second objection, by which, indeed, it was vigorously attacked by the Epicureans, and at length completely driven from the field, is derived from observing that the health or well-being of the general system does not depend upon that of its collective organs; and that some parts are of far more consequence to it than others. Thus the mind, observes Lucretius, in his able refutation of this hypothesis, may be diseased, while the body remains unaffected; or the body, on the contrary, may lose some of its own organs, while the mind, or even the general health of the body itself, continues perfect.

The abbé Polignac, who, consistently with the Cartesian system, makes a very proper distinction between the principle of the mind or soul, and that of the life, enters readily into the hypothesis of Aristoxenus in regard to the latter power, though he thinks it inapplicable to the former: and Leibnitz appears to have availed himself of it as a mean of accounting for the union between the soul and body in his celebrated system, which he seems to have named, from the theory before us, the system of PRE-ESTABLISHED HARMONY. By a writer of the present day, however, M. Lusac, the doctrine of Aristoxenus seems to have been resuscitated in its fullest scope, and even to have been carried to a much wider latitude than its inventor had ever intended: for

the theory of M. Lusac affects to regard, not only the frame of man and other animals, but the vast frame of the universe, as a sort of musical organ or instrument; the concordant and accumulated action of whose different parts or agents he denominates, like Aristoxenus, *harmony*. "Concerts of music," says he, "afford a clear example: you perceive harmony in music when different tones, obtained by the touch of various instruments, excite one general sound, a compound of the whole." This observation he applies to the grand operations of nature, the irregularities of which, resulting from inundations, earthquakes, volcanoes, tempests, and similar evils, this philosopher considers as the dissonances occasionally introduced into music to heighten the harmony of the entire system. With respect to the harmony of the human frame, individually contemplated, or the concordant action of the different parts of the body, he observes, "It may be said, that of this principle I have merely a confused notion; and I admit it, if the assertion imply that I have neither a perfect nor a distinct, nor an entire comprehension of what produces this harmony—in what it consists, or how it acts. I know not what produces the harmony of various instruments heard simultaneously; but I can accurately distinguish the sounds which are occasioned when musicians are *tuning*, from those which are produced when, being completely in tune, and every one uniting in the piece, the

separate parts are executed with precision. When I hear an harmonious sound, whatever be its nature, I can distinguish the harmony, though incapable of investigating its cause.*

I shall only observe, further, that in the doctrine of Mr. (now Sir Humphry) Davy, which holds life itself as a perpetual series of corpuscular changes, and the substrate, or living body, as the being in which these changes take place, we cannot but observe a leaning towards the same system; and we shall have occasion, in a subsequent lecture, to notice one or two others of equally modern date that touch closely upon it in a few points.†

Let us pass on, then, to a consideration of the second hypothesis I have noticed, and which consists in regarding the BLOOD ITSELF AS THE PRINCIPLE OF LIFE. This opinion lays claim to a still higher antiquity than the preceding; and, in a general view of the question, is far better founded. It has the fullest support of the Mosaic writings, which expressly appeal to the doctrine, that "the life of all flesh is the blood thereof,"‡ as a basis for the culinary section of the Levitical code; a doctrine, indeed, of no new invention even at that early period, but probably derived expressly from the ritual of the higher patriarchs, if we may be allowed to appeal to a similar belief and a similar practice

* Du Droit Naturel, Civil, et Politique, tom. i. 154.

† Vol. III. Series III. Lect. v.

‡ Levit. xvii. 14.

among the Parsees, Hindus, and other oriental nations of very remote antiquity, who seem rather to have drawn this part of their ceremonial directly from the law or tradition of the patriarchs, than indirectly from that of the Jews.

Among the Greeks and Romans, were the authority of the poets to be of any avail, we should imagine that this hypothesis never ceased to be in reputation; for the πορφύρεος θάνατος, or *purple death*, of Homer, and the *purpurea anima*, or *purple life*, of Virgil, (phrases evidently derived from this theory), are common-place terms amidst all of them: but the real fact is, that, among the philosophers, we do not know of more than two, Empedocles and Critias, who may be fairly said to have embraced it.

In modern times, however, this hypothesis has again dawned forth, and risen even to meridian splendour, under auspices that entitle it to our most attentive consideration. Harvey, to whom we are indebted for a full knowledge of the circulation of the blood, may be regarded as the phosphor of its uprising; Hoffman speedily became a convert to the revived doctrine; Huxham not only adopted it, but pursued it with so much ardour, as, in his own belief, to trace the immediate part of the blood in which the principle of life is distinctly seated, and which he supposed to be its red particles. But it is to that accurate and truly original physiologist, Mr. John Hunter, that we can only look for a

fair restoration of this system to the favour of the present day, or for its erection upon any thing like a rational basis. By a variety of important experiments, this indefatigable and accurate observer succeeded in proving incontrovertibly that the blood contributes in a far greater degree, not only to the vital action, but to the vital material of the system, than any other constituent part of it, whether fluid or solid. But he went beyond this discovery, and afforded equal proof, not only that the blood is a mean of life to every other part, but that it is actually alive itself. "The difficulty," says he, "of conceiving that the blood is endowed with life, while circulating, arises merely from its being a fluid, and the mind not being accustomed to the idea of a living fluid. — I shall endeavour," he continues, "to show that organization and life do not in the least depend upon each other; that organization may arise out of living parts and produce action, but that life can never arise out of or produce organization." *

This is a bold speculation, and some part of it is advanced too hastily: for instead of its being true, "that life can never arise out of or produce organization," the most cursory glance into nature will be sufficient to convince every man that organization is the ordinary, perhaps the only, mean by which life is transmitted; and

* Hunter on the Blood, p. 20.

that wherever life appears, its tendency, if not its actual result, is nothing else than organization. But though he failed in his reasoning, he completely succeeded in his facts, and abundantly proved that the blood itself, though a fluid and in a state of circulation, is actually endowed with life: for he proved, first, that it is capable of being acted upon and contracting, like the solid muscular fibre, upon the application of a stimulus; of which every one has an instance in that cake or coagulum into which the blood contracts itself when drawn from the arm, probably in consequence of the stimulus of the atmosphere. He proved, next, that in all degrees of atmospherical temperature whatever, whether of heat or cold, which the body is capable of enduring, it preserves an equality in its own temperature; and in addition to this very curious phænomenon, he proved also, that a new-laid egg, the vessels of which are merely in a nascent state, has a power of preserving its proper temperature, and of resisting cold, heat, or putrefaction, for a considerable period longer than an egg that has been frozen, or in any other way deprived of its vital principle. Thirdly, he proved, in the instance of paralytic limbs, that the blood is capable of preserving vitality when every other part of an organ has lost its vital power, and is the only cause of its not becoming corrupt. Fourthly, that though not vascular itself, it is capable, by its own energy, of producing new vessels out of its own substance, and

vessels of every description, as lymphatics, arteries, veins, and even nerves.* Finally, he proved, that the blood, when in a state of health, is not only, like the muscular fibre, capable of contracting upon the application of a certain degree of appropriate stimulus, but that, like the muscular fibre also, it is instantly exhausted of its vital power whenever such stimulus is excessive; and that the same stroke of lightning that destroys the muscular fibre, and leaves it flaccid and uncontracted, destroys the blood, and leaves it loose and uncoagulated.

Important, however, as these facts are, they do not reach home to the question before us. They sufficiently establish the blood to be alive, but they do not tell us what it is that makes it alive: on the contrary, they rather drive us into a pursuit after some foreign and superadded principle; for that which is at one time alive, and at another time dead, cannot be life itself.

The next theory, therefore, to which I have adverted, undertakes to explain in what this foreign and superadded principle consists. Some exquisitely subtle gass or aura—some fine, elastic, invisible fluid, sublimed by nature in the deepest and most unapproachable recesses of her laboratory, and spirited with the most active of her energies. An approach towards this hypothesis is also of great antiquity; for it consti-

* Dr. Munro has proved, that the limb of a frog can live and be nourished, and its wounds heal, without any nerve.

tuted one of the leading features of the Epicurean philosophy, and is curiously developed by Lucretius in his poem on the Nature of Things. According to him, it is a gass or aura, for which in his day there was no name, diffused through every part of the living fabric, swifter and more attenuate than heat, air, or vapour, with all which it concurs in forming the soul or mind as its chief elementary principle: —

> Far from all vision this profoundly lurks,
> Through the whole system's utmost depth diffus'd,
> And lives as soul of e'en the soul itself.[x]

But it is to the astonishing discoveries of modern chemistry alone that we are indebted for any fair application of any such fluid to account for the phænomena of life.

Amongst the numerous gasses which modern chemistry has detected, there are three which are pre-eminently entitled to our attention, though they seem to have been glanced at by the Epicureans: caloric, or the matter of heat, chiefly characterised in our own day as a distinct substance, by the labours of Dr. Black and Dr. Crawford; oxygene, or the vital part of atmospheric air, first discovered by Priestley, and explained by Lavoisier; and the fluid which is collected by the Voltaic trough, and which is

> Nam penitus prorsum latet hæc natura, subestque;
> Nec magis hac infra quidquam est in corpore nostro;
> Atque anima est animæ proporro totius ipsa.
>
> De Rer. Nat. iii. 274.

probably nothing more than the electric fluid under a peculiar form.

Of these caloric, as a distinct entity, was detected first. It was found to be a gass of most astonishing energy and activity, and, at the same time, to be of the utmost consequence to the living substance; to exist manifestly wherever life exists, and to disappear on its cessation. It was hence conceived to be the principle of life itself.

But oxygene began now to start into notice, and the curious and indispensable part it performs in the respiration, as well as in various other functions of both animal and vegetable existence, to be minutely explored and ascertained, and especially by the microscopic eye of M. Girtanner.* The genius of Crawford fell prostrate before that of Lavoisier. Oxygene was now regarded as the principle of life, and heat as its mere attendant or handmaid.

About the year 1790; Professor Galvani, of Bologna, accidentally discovered that the crural nerve of a frog, which had been cut up for his dinner, contracted and became convulsed on the application of a knife wetted with water; and following † up this simple fact, he soon discovered also, that a similar kind of contraction

* Memoires sur l'Irritabilité, considérée comme principe de vie dans la nature organisée. Paris, 1790.

† It is a singular fact, that this identical discovery was not only made, but completed in all its bearings, and by the same means of a recent dissected frog, by Dr. Alexander

or convulsion might be produced in the muscles of other animals, when in like manner prepared for the experiment, not only during life, but for a considerable period after death; and that in all such cases a fluid of some sort or other was either given to the contracting body or taken from it. And Professor Volta, about the same period, succeeded in proving that the fluid thus traced to be given or received was a true electric aura; that it might, in like manner, be obtained by a pile of metallic plates, of two or three different kinds, separated from each other by water, or wetted cloth or wadding; and be so accumulated by a multiplication of such plates, as to produce the most powerful agency in all chemistry. It is not necessary to pursue this subject any farther. Every one in the present day has some knowledge of Galvanism and Voltaism; every one has witnessed some of those curious and astonishing effects which the Voltaic fluid is capable of operating on the muscles of an animal for many hours after death: and it only remains to be added, that since the discovery of this extraordinary power, oxygene has in its turn fallen a sacrifice to the Voltaic fluid, and this last has been contemplated by numerous physiologists as constituting the principle of life; as a fluid received into the animal

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Stuart, physician to the queen, in 1732, though no advantage was taken of it. A minute account of Dr. Stuart's experiments is given in the Phil. Trans. for 1732. See the author's Study of Medicine, vol. iii. p. 29, 2d edit.

system from without, and stimulating its different organs into vital action. "The identity," says Dr. Wilson Phillip, "of Galvanic electricity and nervous influence is established by these experiments."

The result of the whole appears to be, that neither physiology nor chemistry, with all the accuracy and assiduity with which these sciences have been pursued of late years, has been able to arrest or develope the fugitive principle of life. They have unfolded to us the means by which life, perhaps, is produced and maintained in the animal frame, but they have given us no information as to the thing itself; we behold the instrument before us, and see something of the fingers that play upon it, but we know nothing whatever of the mysterious essence that dwells in the vital tubes, and constitutes the vital harmony.

It seems to be on this account, chiefly, that the existence of such a principle as a substantive essence has been of late years denied by MM. Dumas, Bichat, Richerand, Magendie, and, indeed, most of the physiologists of France; whose hypothesis has been caught up and pretty widely circulated in our own country, as though nothing in natural science can be a fair doctrine of belief, unless its subject be matter of clear developement and explanation. But this uncalled for scepticism has involved these philosophers in a dilemma from which it seems impossible for them to extricate themselves, and

which we shall have occasion to notice more fully hereafter: I mean the existence of powers and faculties without an entity or substantial base to which they belong, and from which they originate. They allow themselves to employ the term, and cannot, indeed, do without it; but after all they mean nothing by it. "No one in the present day," says M. Richerand, "contests the EXISTENCE OF A PRINCIPLE OF LIFE, which subjects the beings who enjoy it to an order of laws different from those which are obeyed by inanimate beings; by means of which, among its principal characteristics, the bodies which IT ANIMATES are withdrawn from the absolute government of chemical affinities, and are capable of maintaining their temperature at a near degree of equality, whatever be that of the surrounding atmosphere. Its ESSENCE is not designed to preserve the aggregation of constituent molecules, but to collect other molecules which, by assimilating themselves to the organs that IT VIVIFIES, may replace those which daily losses carry off, and which are employed in repairing and augmenting them."* Yet, when we come to examine

* "Personne aujourd'hui ne conteste l'EXISTENCE D'UN PRINCIPE DE VIE qui soumet les êtres qui en jouissent à un ordre de lois différentes de celles auxquelles obéissent les êtres inanimés, force à laquelle on pourroit assigner, comme principaux characteres, de soustraire les corps qu' ELLE ANIME, à l'empire absolu des affinités chimiques, auxquelles ils auroient tant de tendance à ceder, en virtu de la multiplicité de leurs élémens; et de maintenir leur température à un degré

into the subject more closely, we find that all these terms, so expressive of a specific being and distinct reality — this ESSENCE that VIVIFIES and ANIMATES, has neither being, nor essence, nor vivification, nor animation, nor reality of any kind. That the whole of these expressions are metaphysical; and that the word VITAL PRINCIPLE is not designed to express a distinct being, but is merely an abridged formula, denoting the TOTALITY OF POWERS ALONE which animate living bodies, and distinguish them from inert matter, the TOTALITY OF PROPERTIES and LAWS which govern the animal economy.* So that we have here not only the employment of terms that have no meaning, but properties and laws, powers and principles, without any source, — a superstructure without a foundation, — effects without a cause.

presque égal, quelle que soit d'ailleurs celle de l'atmosphère. Son ESSENCE n'est point de conserver l'aggregation des molécules constitutives, mais d'attirer d'autres molécules qui, s'assimilant aux organes qu' ELLE VIVIFIE, remplacent celles qu'entrainent les pertes journalières, et sont employées à les nourrir, et à les accroître."—Nouveaux Elémens de Physiologie, tom. i. p. 81. 8vo. Paris, 8vo. 1804.

* "Le mot de PRINCIPE VITAL, force vitale, &c. n'exprime point un être existant par lui-même, et indépendamment des actions par lesquelles il se manifeste; il ne faut l'employer que comme une formule abrégée dont on se sert pour désigner l'ensemble des forces qui animent les corps vivans et les distinguent de la matière inerte:—l'ensemble des propriétés et des loix qui regissent l'économie animale." Id. p. 80.

But what is this curious and delicate instrument itself?—this machine that so nicely responds to the impressions communicated to it, and visibly envelopes so invisible a constituent?

It is not my intention in this series of popular study to enter into any minute history of the animal frame, but shall confine myself to those general views of it which are requisite to show by what means it is operated upon by the delicate powers we have just contemplated, and the more curious phænomena which result from such an impulse.

The animal frame, then, is a combination of living solids and fluids, duly harmonized, and equally contributory to each others perfection. The principle of life, whatever it consists of, exists equally in both; in some kinds in a greater, in others in a less degree. In the fluids, Mr. Hunter has traced it down to their first and lowest stage of existence, for he has traced it in the chyle *; and there are evident proofs of its accompanying several of those which are eliminated from the body; in the blood it is found, as we have already had occasion to notice, in a high degree of activity, and probably in a still higher in the nervous fluid.

In the solids it varies equally. There are some in which it can scarcely be traced at all, excepting from their increasing growth, as the cellular membrane, and the bones; in others, we find a perpetual internal activity, or susceptibility to

* On the Blood. p. 91.

external impressions. But it is in those irritable threads or fibres which constitute the general substance of the muscles or flesh of an animal, that the principle of life exerts itself in its most extraordinary manner, and which it more immediately, therefore, falls within the scope of the present lecture to investigate.

The muscle of an animal is a bundle of these irritable fibres, or soft, red, cylindrical, and nearly inelastic threads, formed out of a substance which the chemists, from the use to which it is applied, denominate fibrine; and which, when examined microscopically, are seen to divide and subdivide, as far as the power of glasses will carry the eye, into minuter bundles of fibrils, or still smaller threads, parallel to each other, and bound together by a delicate cellular web-work, obviously of a different nature. They are uniformly accompanied through their course by a number of very minute nerves, which are chords or tubes that originate from the brain, and branch out in every direction, either immediately from the brain itself, or from some part of the spinal marrow, which is a continuation of this organ; by which means a perpetual communication is kept up between the sensorium and the remotest part of the body, as we shall have further occasion to notice hereafter.* Upon the application of any irritating or stimulating power, these fibres immediately contract in their length, and upon the

* Vol. 1. Ser. 1. Lect. xv.

cessation of such power return to their former state of relaxation: and it is chiefly by this curious contrivance that the animal system is enabled to fulfil all its functions. The stimuli by which the fibres, whether of motion or of sensation, are roused into action, are perhaps innumerable in the whole; but a few general classes may easily be devised to comprise all those by which they are ordinarily affected. And while, by an admirable diversity of construction, some sets of fibres are only affected by some sets of stimuli, other sets are only affected by others; and in this manner all the organs are compelled, as it were, to execute the different offices entrusted to them, and no one interferes with that of another. Thus the fibres of the external senses are affected by external objects; they contract and give notice of the presence and degree of power of such objects to the brain, through the medium of the nerves, which, as I have just observed, always accompany them, and which either terminate in or arise from that organ: but while the irritative and sensitive fibres of the ear are excited only by the stimulus of sound, and have no impression produced upon them by that of light, those of the eye are excited only by the stimulus of light, and remain uninfluenced by that of sound: and so of the other organs of external sense. And hence we obtain a knowledge of one set or class of stimuli, which, from their acting upon the organs of sense, are called

sensitive stimuli, and the motions to which they give rise, sensitive motions.

Again, the very substances naturally introduced into many of the muscular organs of the body, and especially the hollow muscles, are sufficient to excite them to a due performance of their functions: thus, the lungs are excited to the act of respiration by the stimulus of the air we breathe, the stomach to that of digestion by the stimulus of the food introduced into it; so the heart and blood-vessels are excited by the stimulus of the blood; and the vessels that carry off the recremental materials, by the different stimuli which these materials contain in themselves. We hence obtain another class of stimuli, which are denominated stimuli of simple irritation; and the motions they produce, simple irritative motions, or motions of irritation.

But the sensory, or brain, which thus receives notice generally, or is imprest upon by the different actions that are perpetually taking place all over the system, through the medium of its own ramifications, or nerves, that uniformly accompany the irritable fibres, in many instances originates motions, and thus proves a stimulus in itself. All voluntary motions are of this kind; the will, which is a faculty of the sensorium, being the exciting cause, and thus giving birth to a third class of stimuli, and of a very extensive range, which are called stimuli of volition. While habit or association becomes, in a

variety of instances, a sufficient impulse to other motions, and thus constitutes a fourth class; which are hence named associate stimuli, or stimuli of association.

But though the muscular fibre is, perhaps, more irritable than any other part of the system, the principle of irritability and a fibrous structure are by no means necessarily connected; for, while the cellular membrane is fibrous but has no irritability whatever, the skin is not fibrous but is highly irritable.

Hence solids and fluids are equally necessary to the perfection of the living system. Food, air, and the etherial gasses, caloric, oxygene, and the medium of electricity, are the stimuli by which it is chiefly excited to action; and, by their combination, contribute in some degree to the matter of the system itself; but of the mysterious power that developes the organs and applies the stimuli, that harmonizes the action and constitutes the life, we know nothing.

We see clearly, however, that the moving powers are, for the most part, the muscles; and it is a subject of perpetual astonishment to the physiologist to observe the prodigious force which these vital cords are made capable of exerting, and the infinite variety of purposes to which they thus become subservient. And were it not that the whole universe swarms with proofs of intelligence and design—were it not

that there exists, to adopt the beautiful words of the poet —

> Books in the running brooks,
> Sermons in stones, and good in every thing —

this, perhaps, might be the part of creation which we could best select in proof of the wisdom of the Creator.

It was formerly too much the custom to regard the animal frame as a mere mechanical machine; whence, in that spirit of absurdity with which the wisest of mankind are occasionally afflicted, Descartes affected to believe that brutes are as destitute of consciousness as a block of wood, and that it is exactly the same sort of necessity which drives a dog forward in pursuit of a hare, that compels the different pipes of an organ to give forth different tones upon a pressure of the fingers against its different keys. It is not every one, however, in modern times who has adopted the mechanical theory that has carried it to this extremity of absurdity; but all of them are still carrying it too far who reason concerning the principal motions of the body as mere mechanical motions, and the powers which the muscles exert as mere mechanical powers; in which the bones are the levers, the joints the fulcra, and the muscles the moving cords; for it so happens that all the effects for which the whole of this complicated machinery is absolutely necessary out of the body, are in many instances performed by a single part of it within the body,

namely, by the moving cords or muscles alone, without either bones or joints, levers or fulcra. I do not mean to contend that there is no kind of resemblance or conformity of principle between the laws of animate and inanimate mechanics, for I well know that in a variety of points the two systems very closely concur; but I am obliged to contend that they are still two distinct systems, and that in the one case the living power exercises an influence which finds no sort of similitude in the other.

It is indeed curious to observe the difference of result which has flowed from the calculations of the different promoters of this theory; and which alone, were there nothing else to oppose them, would be sufficient to prove the fallacy of their reasoning. Among those who have adopted this mode of explanation, and have pursued it with most acuteness, and may be regarded as the fathers of the school, I may be allowed to mention Borelli and Keil; but while the former, in order to account for the circulation of the blood in man, calculated the force with which the heart contracts to be equal to not less than a hundred and eighty thousand pounds weight at every contraction, the latter could not estimate it at more than eight ounces.

In like manner Borelli, in applying the same theory to the power with which the human stomach triturates, or, as we now call it, digests its food, calculated it, in conjunction with the assistance it receives from the auxiliary muscles,

which he conceived to divide the labour about equally with itself, as equal to two hundred sixty-one thousand one hundred and eighty-six pounds; and Pitcairn has made it very little less, since he estimates the moiety contributed by the stomach alone at one hundred and seventeen thousand and eighty-eight pounds; which gives to these organs jointly a force more than equal to that of twenty mill-stones! "Had he," says Dr. Monro, "assigned five ounces as the weight of the stomach, he had been nearer the truth." *

The fallacy of this theory, however, and especially as it applies to the stomach, has been completely exposed in our own day, by the well-ascertained fact, that though the muscular coat of the stomach in most animals bears some part in the process of digestion, this important operation is almost entirely performed by a powerful chemical solvent secreted by the stomach itself for this very purpose, and hence denominated the gastric juice; and which answers all the purposes of the most violent muscular pressure we can conceive, and with a curious simplicity of contrivance.

The laws of physical force will certainly better apply to the action of the heart and arteries than to that of the stomach, and in some measure assist us in accounting for the circulation of the blood; but the moment we reflect that

* Comp. Anat. pref. p. viii. note.

one half of this very circulation, that I mean which depends upon the veins, and which has for the most part to contend against the attraction of gravitation, instead of being able to avail itself of its assistance, is produced without any muscular propulsion that we are able to discover, and that even the arteries do not, when uninfluenced by pressure, appear to change their diameter in a state of health *, we are necessarily driven to the conclusion, that there is in animal statics, as well as in animal mechanics, a something distinct and independent, and which the laws of physical force are altogether incompetent to explain. Dr. Young, in his excellent Croonian lecture, read before the Royal Society in 1809 †, has endeavoured to revive the mechanical theory; but he is still compelled to admit a variety of phænomena in the animal machine, and especially in the circulatory system, which are altogether unaccountable upon any of the known principles of common hydraulics, and which can never fail to reduce us to the same result.

So far, therefore, as we at present know, the circulation of the blood is performed by a double projectile power; one moiety being dependent on the action of the living principle in the heart, and perhaps the arteries; and the other moiety on the common law of hydraulics, or the vacuum

* See Lect. VIII. p. 201, as also the author's Study of Medicine, vol. ii. p. 16. Edit. second, 1825.

† On the Functions of the Heart and Arteries, Phil. Trans. 1809, p. 1.

produced in the heart by that very contraction or systole which has just propelled the blood returned from the lungs into the arterial system. Whence the heart itself becomes alternately a forcing and a suction pump; being the former in respect to the arteries, and the latter in respect to the veins. *

Upon a moderate estimate, the common labourer may be said to employ a force capable of raising a weight of ten pounds to the height of ten feet in a second, and continued for ten hours a day. A moderate horizontal weight for a strong porter, walking at the rate of three miles an hour, is 200 pounds: the chairman walks four miles an hour, and carries 150 pounds. The daily work of a horse is equal to that of five or six men upon a plane; but from his horizontal figure, in drawing up a steep ascent, it does not exceed the power of three or four men. In working windmills, twenty-five square feet of the sails is equivalent to the work of a single labourer; whence a full-sized mill, provided it could be made to work eight hours a day, would be equivalent to the daily labour of thirty-four men. A steam engine of the best construction, with a thirty-inch cylinder, has the force of forty horses; and, as it acts without intermission, will perform the work of 120 horses, or of 600 men; every square inch of the piston being equivalent to the power of a labourer.

* See Stud. of Med. vol. ii. p. 19. ed. second.

There are many muscles given to us which the common customs and habits of life seldom render it necessary to exert, and which in consequence grow stiff and immoveable. Tumblers and buffoons are well aware of this fact; and it is principally by a cultivation of these neglected muscles that they are able to assume those outrageous postures and grimaces, and exhibit those feats of agility, which so often amuse or surprise us.

The same muscles of different persons, however, though of the same length and thickness, and so far as we are able to trace, composed of the same number of fibres, are by no means uniformly possessed of the same degree of power; and we here meet with an express deviation from the law of physical mechanics; as we do also in the curious fact, that whatever be the power they possess, they grow stronger in proportion to their being used, provided they are well used, and not exhausted by violence or over-exertion.

I have calculated the average weight carried by a stout porter in this metropolis at 200 pounds; but we are told there are porters in Turkey, who, by accustoming themselves to this kind of burden from an early period, are able to carry from 700 to 900 pounds, though they walk at a slower rate, and only carry the burden a short distance. "The weakest man can lift with his hands about 125 pounds, a strong man 400. Topham, a carpenter, mentioned by Desaguliers, could lift 800 pounds. He rolled

up a strong pewter dish with his fingers. He lifted with his teeth and knees a table six feet long, with a half hundred weight at the end. He bent a poker, three inches in circumference, to a right angle, by striking it upon his left fore-arm; another he bent and unbent about his neck, and snapped a hempen rope two inches in circumference. A few years ago there was a person at Oxford who could hold his arm extended for half a minute, with half a hundred weight hanging on his little finger."* We are also told by Desaguliers of a man who, by bending his body into an arch, and having a harness fitted to his hips, was capable of sustaining a cannon weighing two or three thousand pounds. And not many winters ago, the celebrated Belzoni, when first entering on public life, exhibited himself to the theatres of this metropolis, and by a similar kind of harnessing was capable of supporting, even in an upright position, a pyramid of ten or twelve men surmounted by two or three children, whose aggregate weight could not be much less than 2000 pounds; with which weight he walked repeatedly towards the front of the stage.

The prodigious powers thus exerted by human muscles will lead us to behold with less surprise the proofs of far superior powers exerted by the muscles of other animals, though it will by no means lead us to the means of accounting for such facts.

* Young's Lect. on Nat. Phil. i. 129.

The elephant, which may be contemplated as a huge concentration of animal excellencies, is capable of carrying with ease a burden of between three and four thousand pounds. With its stupendous trunk (which has been calculated by Cuvier to consist of upwards of thirty thousand distinct muscles) it snaps off the stoutest branches from the stoutest trees, and tears up the trees themselves with its tusks. How accumulated the power that is lodged in the muscles of the lion! With a single stroke of his paw he breaks the back-bone of a horse, and runs off with a buffalo in his jaws at full speed: he crushes the bones between his teeth, and swallows them as a part of his food.

Nor is it necessary, in the mystery of the animal economy, that the muscles should always have the benefit of a bony lever. The tail of the whale is merely muscular and ligamentous; and yet this is the instrument of its chief and most powerful attack; and possest of this instrument, to adopt the language of an old and accurate observer*, "a long boat he valueth no more than dust, for he can beat it all in shatters at a blow." The skeleton of the shark is entirely cartilaginous, and totally destitute of proper bone; yet is it the most dreadful tyrant of the ocean: it devours with its cartilaginous jaws whatever falls in its way; and in one of its species, the squalus *carcharias*, or white shark,

* Frederick Martens. See Shaw, II ii. 489

which is often found thirty feet long, and of not less than four thousand pounds weight, has been known to swallow a man whole at a mouthful.

The sepia *octopodia*, or eight-armed cuttle-fish — the polypus of Aristotle — is found occasionally of an enormous size in the Mediterranean and Indian seas, its arms being at times nine fathoms in length, and so prodigious in their muscular power, that when lashed round a man, or even a Newfoundland dog, there is great difficulty in extricating themselves; and hence the Indians never venture out without hatchets in their boats, to cut off the animal's holders, should he attempt to fasten on them, and drag them under water.

But this subject would require a large volume, instead of occupying the close of a single lecture. Let us turn from the great to the diminutive. How confounding to the skill of man is the muscular arrangement of the insect class! Minute as is their form, there are innumerable tribes that unite in themselves all the powers of motion that characterise the whole of the other classes; and are able, as their own will directs, to walk, run, leap, swim, or fly, with as much facility as quadrupeds, birds, and fishes exercise these faculties separately. But such a combination of functions demands a more complicated combination of motive powers; and what it demands it receives. In the mere larve or caterpillar of a cossus, or insect approaching to the butterfly, Lyonet has detected not less than

four thousand and sixty-one distinct muscles, which is about ten times the number that belong to the whole human body; and yet it is probable that these do not constitute any thing like the number that appertain to the same insect in its perfect state. The élator *noctilucus*, or phosphorescent springer, is a winged insect; but it has also a set of elastic muscles, which enable it, when laid on its back, to spring up nearly half a foot at a bound, in order to recover its position. This insect is also entitled to notice in consequence of its secreting a light, which is so much beyond that of our own glow-worm, that a person may see to read the smallest print by it at midnight. The cicada *spumaria*, or spumous grasshopper, is in like manner endowed with a double power of motion; and when attempted to be caught will either fly completely off, at its option, or bound away at the distance of two or three yards at every leap. This insect is indigenous to our own country, and is one of those which in their larve and pupe states discharge, from the numerous pores about the tail, that frothy material upon plants which is commonly known by the name of cuckow-spit.

Crabs and spiders have a strong muscular power of throwing off an entire limb whenever seized by it, in order to extricate themselves from confinement; and most of them throw off also, once a year, their skin or crustaceous covering, and secrete a new one. The muscular elasticity of the young spider gives it, moreover,

the power of wings; whence it is often seen, in the autumn, ascending to a considerable elevation, wafted about by the breeze, and filling the atmosphere with its fine threads. The land-crab (cancer *ruricola*) inhabits the woods and mountains of a country; but its muscular structure enables it to travel once a year to the sea-coast to wash off its spawn in the waters. The spawn or eggs thus deposited sink into the sands at the bottom of the sea, and are soon hatched; after which millions of little crabs are seen quitting their native element for a new and untried one, and roving instinctively towards the woodlands.

The hinge of the common oyster is a single muscle; and it is no more than a single muscle in the chama gigas, or great clamp-fish, an animal of the oyster form, but the largest testaceous worm we are acquainted with. It has been taken in the Indian ocean of a weight not less than 532 pounds; the fish, or inhabitant, being large enough to furnish 120 men with a meal, and strong enough to lop off a hand with ease, and to cut asunder the cable of a large ship.

Nor is the muscular power allotted to the worm tribes less wonderful than that of insects, or its variety less striking and appropriate. The leech and other sucker-worms are as well acquainted with the nature of a vacuum as Torricelli; and move from place to place by alternately converting the muscular disks of their head and tail into air-pumps.

The sucker of the cyclopterus, a genus of fishes denominated suckers from their wonderfully adhesive property, is perhaps the most powerful, for the size of the fish, of any we are acquainted with; and is formed, at will, by merely uniting the peculiar muscles of its ventral fins into an oval concavity. In this state, if pulled by the tail, it will raise a pail-full of water rather than resign its hold.

The teredo *navalis*, or ship-worm, is seldom six inches in length, but the muscles and armour with which its head is provided enables it to penetrate readily into the stoutest oak-planks of a vessel, committing dreadful havoc among her timbers, and chiefly producing the necessity for her being copper-bottomed. This animal is a native of India; it is gregarious, and always commences its attack in innumerable multitudes; every worm, in labouring, confining itself to its own cell, which is divided from that of the next by a partition not thicker than a piece of writing paper. The seaman, as he beholds the ruin before him, vents his spleen against the little tribes that have produced it, and denounces them as the most mischievous vermin in the ocean. But a tornado arises — the strength of the whirlwind is abroad — the clouds pour down a deluge over the mountains — and whole forests fall prostrate before its fury. Down rolls the gathering wreck towards the deep, and blocks up the mouth of that very creek the seaman has entered, and

where he now finds himself in a state of captivity. How shall he extricate himself from his imprisonment?—an imprisonment as rigid as that of the Baltic in the winter-season. But the hosts of the teredo are in motion:—thousands of little augers are applied to the floating barrier, and attack it in every direction. It is perforated, it is lightened, it becomes weak; it is dispersed, or precipitated to the bottom; and what man could not effect, is the work of a worm. Thus is it that nothing is made in vain; and that in physics, as well as in morals, although evil is intermingled with good, the good ever maintains a predominancy.

LECTURE XI.

ON THE BONES, CARTILAGES, TEETH, ARTICULATION, INTEGUMENTATION, HAIR, WOOL, SILK, FEATHERS, AND OTHER HARD OR SOLID PARTS OF THE ANIMAL FRAME.

In a former lecture we took a general survey of the characteristic features that distinguish the unorganized from the organized world, and the vegetable kingdom from the animal: we examined into the nice structure of plants, and the resemblances which they bear to the animated form. In our last lecture we proceeded to an enquiry into the nature of the living principle, took a glance at a few of the theories that have been invented to explain its essence and mode of operation, and contemplated the origin and powers of the muscular fibre, which may be denominated its grand executive organ.

The muscles of an animal, however, are not the only instruments of animal motion; the bones, cartilages, and ligaments contribute very largely to the action, and the skin is not unfrequently a substitute for the muscle itself. These, therefore, as well as a variety of other bodies minutely connected with them, or evincing a

similarity of construction,—as the teeth, hair, nails, horns, shells, and membranes,—are now to pass under our review, and are entitled to our closest attention; and I may add, that their diversity of uses and operations, and the curious phænomena to which they give rise, are calculated to afford not less amusement than instruction.

I had occasion to remark lately *, that lime is a substance absolutely necessary to the growth of man. It is, in truth, absolutely necessary to the growth of almost all animals; even soft-bodied or molluscous worms, except in a few instances, are not free from it; nay, even infusory animals, so minute as to be only discerned by the microscope, still afford a trace of it in the calcareous speck which constitutes their snout: but it is in the bones and shells of animals that lime is chiefly to be found; and hence those animals possess most of it in whom these organs are most abundant.

Bone, shell, cartilage, and membrane, however, in their nascent state, are all the same substance, and originate from a viscid fluid, usually supposed to be the coagulable lymph, or more liquid part of the blood; which, secreted in one manner, constitutes jelly, or gelatine, a material characterised by its solubility in warm water, heated to about half the boiling point; and,

* Vol. I. Series I. Lect. VI. On Geology, p. 141, and passim; and Lect. VIII. On Organized Bodies, and the Structure of Plants compared with that of Animals, p. 171.

secreted in another manner, forms albumen, or the material of the white of the egg, characterized by its coagulating instead of dissolving in about the same heat: the difference, however, between the two, consisting merely, perhaps, in the different proportion of oxygene they contain. Membrane is gelatine, with a small proportion of albumen to give it a certain degree of solidity; cartilage is membrane, with a larger proportion of albumen to give it a still greater degree of solidity; and bone and shell are mere cartilage, hardened by the insertion of lime into their interior, the lime being secreted for this purpose by a particular set of vessels, and absorbed by the bony or shelly rudiments in their soft state. And hence any substances which, like the mineral acids, for example, have a power of dissolving the earthy matter of the two last, and of leaving the cartilage untouched, may be readily employed as re-agents, to reduce them to their primary softness: and it was by this mean that Cleopatra, as we are told by Pliny, dissolved one of the costly pair of pearls that formed her ear-rings, each of which was valued at upwards of eighty thousand pounds (*centies sestertium*), at a feast given to Marc Antony, and then presented it to him in a goblet, with an equal mixture of wine.*

* This was on a trial who could give the most sumptuous banquet. Munacius Plancus was the arbiter. The expence of Marc Antony's, already bestowed, had been valued at just the price of this single pearl. Cleopatra was proceeding to dis-

In the adult state, however, as well as in the embryo state, it is necessary that the bones, like every other substance of the animal frame, should be punctually supplied with the elementary matter, or the means of forming the elementary matter, of which it essentially consists, the old matter of every kind being worn out by use, and carried away by a distinct set of vessels, called lymphatics or absorbents. It is the office of the digestive organs to receive such supply from without, and to prepare it for the general use. And hence, if we could conceive it possible for these organs, or any organs dependent upon them, to be so peculiarly diseased as to be incapable of preparing or conveying to the bones a sufficient quantity of lime, (of which some portion is contained in almost every kind of food,) to supply the place of that which is perpetually passing off, the necessary consequence would be, that the bones would progressively lose their hardness, and become cartilaginous and pliable. Now we sometimes do meet with the digestive or the secretory organs affected by such a kind of disease, and that both in children and adults. In children it is more common, and is called RICKETS; in grown persons it is simply called a SOFTNESS OF THE BONES, or MOLLITIES OSSIUM. In the former case, the

solve its fellow, when she was suddenly stopped by the umpire, who declared the victory to be hers. Plin. Hist. Nat. lib. ix. 35.

softened spine becomes bent from the weight of the head, and other extremities, which it is now no longer able of sustaining, while the chest and most of the limbs partake of the general distortion. In the latter case many of the bones are sometimes reduced to imperfect cartilages, and can be bent and unbent in any direction.

Lime, however, is never found in the animal system in its pure state, and is certainly never introduced into it in such a state. It is usually combined with some acid, either the phosphoric, in which case the compound is called phosphate of lime, or carbonic acid gass, when it is called carbonate of lime, or common chalk.

It is of no small importance to attend to the nature of these two acids; for it is the difference between them that chiefly constitutes the difference between bones and shells; bones uniformly consisting of a larger proportion of phosphate of lime, or lime and phosphoric acid, and a less proportion of carbonate; and shells of a larger proportion of carbonate of lime, and a less proportion of phosphate. There are a few other ingredients that enter into the composition of both these substances, and which are chiefly obtained from the materials of common salt, as sulphuric acid and soda; but the proportions are too small to render it necessary to dwell upon them in a course of popular study. Bones, shells, cartilages, and membranes may therefore be regarded as substances of the same kind,

differing only in degree of solidity from the different proportions that they possess of albumen and salts of lime.

Teeth, horn, coral, tortoise-shell, fish-scales, and the crustaceous integuments of crabs, millepedes, and beetles, are all compounds of the same elements combined in different proportions, and rendered harder or softer as they possess a larger or smaller quantity of calcareous salts; ivory and the enamel of teeth possessing the largest quantity, and consisting almost exclusively of phosphate of lime, with a small proportion of animal matter.

The gelatine and albumen are unquestionably generated in the animal system itself from the different substances it receives under the form of food; and it is curious to observe the facility and rapidity with which some animals are capable of producing them. The gastrobranchus *cœcus*, or hag-fish, a small lamprey-like animal of not more than eight inches long, will convert a large vessel of water in a short period of time into size or mucilage, of such a thickness that it may be drawn out in threads. The form and habits of this little animal are singular: Linnéus regarded it as a worm; but Bloch has removed it, and with apparent propriety, into the class of fishes. It is a cunning attendant upon the hooks of the fisherman; and as soon as it perceives a larger fish to be taken, and by its captivity rendered incapable of resistance, it darts

into its mouth, preys voraciously, like the fabled vultures of Prometheus, on its inside, and works its way out through the fish's skin.

But though gelatine and albumen are unquestionably animal productions, the one a secretion from the blood, and the other a constituent principle of it, there is a doubt whether lime ought ever to be regarded in the same character. A very large portion is perpetually introduced into the stomach from without. In our lecture on the analogy between the structure of plants and of animals *, I had occasion to observe, that it forms an ingredient in common salt; not, indeed, necessarily so, but from the difficulty of separating the other ingredients from their combination with it: yet it enters not more freely into common salt than into almost every other article, whether animal, vegetable, or mineral, of which our diet is usually composed. And upon this common fact it is more generally conceived, at present, to be a substance communicated to the animal frame, than generated by it.

This opinion, however, is by no means established; and there are many circumstances that may lead us to a contrary conclusion. Though almost every kind of food contains some portion of lime, it by no means contains an equal portion; and yet we find that a healthy young animal, whatever be the sort of food on which it is fed, will still provide lime enough from

* Vol. I. Ser. I. Lect. VIII.

some quarter or other to satisfy the demand of its growing bones, and to maintain them in a due degree of solidity and hardness.

Again, the soil of some countries, as the mountains of Spain, for example, consists almost entirely of gypsum or some other species of limestone; while in other countries these are substances very rarely to be met with. It is a curious fact, that in that vast part of the globe which has been latest discovered, and to which modern geographers have given the name of Australia, comprising New Holland and the islands with which its shores are studded, not a single bed or stratum of limestone has hitherto been detected, and the builders are obliged to make use of burnt shells for their mortar, for which I have lately advised them to substitute burnt coral. * Now, it would be natural to suppose that the animals and vegetables of such a country would partake of the deficiency of its soil, and that the shells and bones which it produces would be less compact in their texture than those of other countries; yet this supposition is not verified by fact: nature is still adequate to her own work; the bones of animals are as indurated and perfect in these regions as in any parts of the old world; while the shells are not only as perfect, but far more numerous; and the frequent reefs of coral,

* It is understood that some beds of chalk have since been discovered on the farther side of the Blue Mountains; but none is still to be traced on the hither side, in any of the settlements of the colony.

altogether an animal production, that shoot forth from the shores in bold and massy projections, prove clearly that a coral rock, largely as it consists of lime, forms the basis of almost every island.

The prodigious quantity of lime, moreover, that is secreted by some animals at stated periods, beyond what they secrete at other times, seems to indicate a power of generating this earth in their own bodies. The stag, elk, and several other species of the deer tribe, cast their antlers annually, and renew them in full perfection in about twelve weeks. These antlers are real bones; and those of the elk are sometimes as heavy as half a hundred pounds weight, and in a fossil state in Ireland have been dug up still heavier, and of the enormous measure of eight feet long, and fourteen feet from tip to tip; on beholding which, we may well, indeed, exclaim with Waller, —

> O fertile head! which every year
> Could such a crop of wonders bear.

In like manner, many species of the crab and lobster tribes annually throw off and renew the whole of their crustaceous covering, and apparently without any very great degree of trouble. The animal at this time retires to some lonely and sheltered place, where, in its naked and defenceless state, it may avoid the attack of others of the same tribe which are not in the same situation: a line instinctively drawn now separates the shell into two parts, which are

easily shaken off, when the secernent vessels of the skin pour forth a copious efflux or sweat of calcareous matter all over the body, the more liquid parts of which are as rapidly drunk up by the absorbent vessels, so that a new calcareous membrane is very soon produced, which as speedily hardens into a new calcareous crust, and the entire process is completed in about a fortnight. This genus, also, in many of its species, is capable of reproducing an entire limb, with the whole of its calcareous casing, whenever deprived of it by accident or disease, or it voluntarily throws it off, as I have already observed it is capable of doing, to extricate itself from being seized hold off; though the new limb is seldom so large or powerful as the original. So, in other animals we sometimes find a large and preternatural secretion of calcareous matter, in consequence of a diseased habit of particular organs, or of the system generally. The human kidneys are too often subject to a morbid affection of this kind, whence a frequent necessity for one of the most painful operations in surgery. The chalk-stones, as they are erroneously called, that are often produced in protracted fits of gout and rheumatism, are rather lithate of soda than any compound of lime; but instances are not wanting in which one of the lungs has been found converted into an entire quarry of limestone.

In the Transactions of the Royal Society there are several cases related of young persons who,

in consequence of a morbid habit, threw out a variety of calcareous excrescences, either over the hands and feet, or over the whole body *; and about four years since, a Leicestershire heifer was exhibited for a show in this metropolis, the head and neck of which were completely embedded in horny excrescences of this kind, and the back and limbs profusely sprinkled over with them: some of the horns, and especially those about the dew-lap, were as long and as large as the natural horns of the forehead, but they were much more calcareous and brittle. A calcareous scurf, moreover, was secreted over every part of the skin, which, whenever the skin was scratched or bitten, united with the fluid that oozed forth, ramified, and divaricated into masses of small roses. At the request of the proprietor I took an account of this extraordinary animal, and have since communicated it to the Royal Society. In all other respects it was in good health; its size was proportionate to its [illegible]mer, its appetite enabled it to digest fsequently the kind equally; and though, [illegible]ily on the coast of this, its diet had been firrequently on that of propensity to a secretivas traced some centuries continued the same urce in the river Conway in

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* See also M[illegible]
Phil. Trans. fo[illegible]

out of the different materials introduced into the stomach in the form of food. Vauquelin endeavoured to decide the question by a variety of experiments upon the nature of the egg-shells of a sitting hen, and an examination into the proportion of calcareous matter contained in a given weight of shells, compared with the calcareous matter furnished by her food, and that discharged as a recrement; and, so far as these experiments go, they support the opinion of a generation of lime, and that in very considerable abundance, the weight secreted appearing to have been five times as much as that introduced into the stomach. But to determine the question incontrovertibly requires so nice a precision in the mode of conducting such experiments, as, from a variety of circumstances, it seems almost impossible to attain.

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which in Spain, Portugal, and even Holland, were lately worn as amulets against contagion, and which have been let out for hire at a ducat a day, and been sold as high as three hundred guineas a piece; and those delicate pearls which constitute an object of desire among the fair sex of every country, and which give additional attraction to the most finished form.

The first are usually obtained from the stomach or intestines of the goat or antelope; in the latter case being called oriental bezoards, and possessing the highest value. The most esteemed are those obtained from the stomach of that species of the oriental antelope called the gazel, to which the Persian and Arabian poets are perpetually adverting whenever they stand in need of an image to express elegance of form, fleetness of speed, or captivating softness of the eyes. The second are obtained from the inside of the shells of the mytilus *margaritiferus* and mya *margaritifera*, pearl-muscle and pearl-oyster; the former, producing the largest and consequently the richest, is found most commonly on the coast of Ceylon; the latter not unfrequently on that of our own country, and was traced some centuries ago in great abundance in the river Conway in Wales. Linnéus is said to have been acquainted with a process by which he could excite at pleasure a secretion of new pearls in the pearl-oysters which he kept in his reservoirs. It is generally supposed to be a diseased secretion somewhat

similar to that of the stone in the human bladder.

The murex *tritonis*, or musical murex, is here also worth noticing. Its calcareous shell is ventricose, oblong, smooth, with rounded whorls, toothed aperture, and short beak, about fifteen inches long, white, and appearing as if covered with brown, yellow, and black scales. It inhabits India and the South Seas, and is used by the New Zealanders as a musical shell, and by the Africans and many nations of the East as a military horn.

Before we quit this subject, I will just observe, that it is to the same tribe we are indebted for our nacre or mother-of-pearl, which is nothing more than the innermost layers of the shell, in which the morbid works or concretions which we call pearls lie embedded; and that to the same order of shells the Indians owe their wampum or pieces of common money, which are formed of the Venus *mercenaria*, or clam-shell, found in a fossil state; and that our own heralds owe the scallop, ostrea *maxima*, that so often figures in the field of our family arms, and was formerly worn by pilgrims on the hat or coat, in its natural state, as a mark that they had crossed the sea for the purpose of paying their devotions at the Holy Land.

From these facts and observations we cannot but behold the great importance of lime in the construction of the animal frame, the extensive

use which is made of it, and the variety of purposes to which it is applied: combined in different proportions with gluten and albumen it affords equally the means of strength and protection, produces the bones within and the shells without, the external and internal skeleton, and is discoverable in every class, order, and even genus of animals, except a very few of the soft worms and insects in their first and unfinished state.

It is hence the cerambyx, and several other tribes of insects, are able to make that shrill sound which they give forth on being taken, and which appears like a cry from the mouth, but is in reality nothing more than the friction of the chest of the insect against the upper part of its abdomen and wing-shells. And it is hence, also, that the ptinus *fatidicus*, or death-watch, produces those measured strokes against the head or other part of a bed in the middle of the night, which are so alarming to the fearful and superstitious; but which in truth are nothing more than a call or signal by which the one sex is enticed to the other, and is merely produced by the insect's striking the bony or horny front of its head against the bed-post, or some other hard substance.

Having, then, taken a brief survey of the elementary nature and chemical composition of these harder parts of the animal frame, I shall proceed to make a few remarks upon the relative

powers of each, and their diversified applications amidst the different kinds of animals in which they are employed.

The BONES in their colour are usually white; but this does not hold universally, for those of the gar-pike (esox *Belone*) are green; and in some varieties of the common fowl they approach to a black: Abelfazel remarks this of the fowls of Berar, and Niebuhr of those of Persepolis.

The bones of an animal, wherever they exist, are unquestionably the levers of its organs of motion: and so far the mechanical theorists are correct. In man and quadrupeds, whose habits require solidity of strength rather than flexibility of accommodation, they are hard, firm, and unpliant, and consist of gluten fully saturated with phosphate and carbonate of lime. In serpents and fishes, whose habits, on the contrary, demand flexibility of motion, they are supple and cartilaginous; the gluten is in excess, and the phosphate of lime but small in proportion to it, and in some fishes altogether deficient in the composition of their skeleton, though still traceable in their scales and several other parts. In birds, whose natural habits demand levity, the bones are skilfully hollowed out and communicate with the lungs, and instead of being filled with marrow are filled with air, so that the purpose for which the structure of birds was designed is as obvious, and as deeply marked, in the bones as in the wings, whose quills also are

for the same reason left hollow, or rather are filled with air, and in many tribes communicate with the lungs as the bones do.

The skeleton of the cuttle-fish (sepia *officinalis*) is extremely singular: its back-bone, for some purpose unknown to us, is much broader than that of any other aquatic animal of the same size, and of course would be much heavier but for a curious contrivance to prevent this effect, which consists in its being exquisitely porous and cellular, and capable, like the bones of birds, of becoming filled with air, or exhausted of it, at the option of the animal, in order to ascend or descend with the greater facility. It is an animal of this kind, or closely akin to it*, that inhabits the shell of the beautiful paper-nautilus, and still more beautiful pearl-nautilus (argonauta and nautilus tribes), and which hence obtain no inconsiderable portion of that lightness which enables them, with their extended sails, to scud so dextrously before the wind. In the calamary

* The animal has commonly been supposed to be a real sepia or cuttle-fish; but several naturalists have of late doubted this, inasmuch as there are a few marks of distinction that seem to take it out of this genus. Rafinesque has hence made another genus, for the purpose of receiving those which possess these distinctive signs; and Dr. Leach has lately distinguished it specifically, in consequence of specimens sent home from the unfortunate Congo expedition, as collected by Cranch, by the name of Ocythoe *Cranchii*. Even this animal, however, is regarded as a parasite in the shell, and only possessing it when empty. The proper animal is not known to the present hour. See Phil. Trans. 1817, p. 293.

(sepia *Loligo*) we meet with an approach towards the same contrivance, in a kind of leafy plate introduced into the body of the animal; and even in the cloak of the slug tribe we trace something of the same sort, though proportionably smaller, and verging to the nature of horn.

Generally speaking, the bones grow cartilaginous towards their extremities, and the muscles tendinous; by which means the fleshy and osseous parts of the organs of motion become assimilated, and fitted for that insertion of the one part into the other upon which their mutual action depends. The extent and nature of the motion is determined by the nature of the articulation, which is varied with the nicest skill to answer the purpose intended. In ostraceous worms the only articulation is that of the hinge: in the cancer tribes the tendon is articulated with the crust, whence the wonderful strength and activity of the claws; and it is articulated in a similar manner with the scaly plates of some species of the tortoise. In insects the part received and the part receiving form each a segment of a spheroid; whence the motion may be either rotatory or lateral, at pleasure. In mammalian animals the lower jaw only has a power of motion; but in birds, serpents, and fishes the upper jaw in a greater or less degree possesses a similar power.

The motion of serpents is produced, according to Sir Everard Home, by their ribs, which for

the most part accompany them, not only as organs of respiration, but from the hind extremity to the neck, and are possest of a peculiar power of motion by means of peculiar muscles. "The vertebræ are articulated by ball and socket-joints (the ball being formed upon the lower, and the socket on the upper one), and have therefore much more extensive motion than in other animals." In the draco *volans* the skeleton of the wings is formed out of ribs which "are superadded for this purpose, and make no part of the organs of respiration; the ribs in these animals appear to work in succession, like the feet of a caterpillar."

The TEETH vary in their form and position almost as much as the bones. Where jaw-bones exist they are usually fixt immoveably in their sockets; but in some animals a few of them are left moveable, and in others the whole. The mus *maritimus*, or African rat, the largest species of this genus which has hitherto been discovered, and seldom less than a full-sized rabbit, has the singular property of separating at pleasure to a considerable distance the two front-teeth of the lower jaw, which are not less than an inch and a quarter long. That elegant and extraordinary creature the Kangaroo, which, from the increase that has lately taken place in his Majesty's gardens at Kew, we may soon hope to see naturalized in our own country, is possessed of a similar faculty. And the hollow tusks or poisoning

fangs of the rattle-snake, and other deadly serpents, are situated in a peculiar bone on each side of the upper jaw, so articulated with the rest, that the animal can either depress or elevate them at his option. In a quiescent state they are recumbent, with their points directed inwards; but whenever the animal is irritated he instantly raises them; and at the moment they inflict a wound, the poison, which lies in a reservoir immediately below, is injected through their tubes by the act of pressure itself.

In the shark and ray genera the whole of the teeth are moveable, and lie imbedded in jaw-cartilages instead of in jaw-bones, and like the fangs of the poisonous serpents are raised or depressed at pleasure. The teeth of the xiphias *Gladius*, or sword-fish, are similarly inserted; while his long sword-like snout is armed externally, and on each side, with a taper row of sharp, strong, pointed spines or hooks, which are sometimes called his teeth, and which give rise to his popular name.

The ant-eater and manis swallow their aliment whole: and in many animals the jaws themselves perform the office of teeth, at least with the assistance of the tongue. In birds this is generally the case, sometimes in insects, whose jaws are for this purpose serrated or denticulated at the edge, and frequently in molluscous worms. The jaws of the triton genus act like the blades of a pair of scissars. The snail and slug have only a single

jaw, semilunar in its form, and denticulated: but the mouth of the nereis has several bony pieces. The sea-mouse (aphrodita *aculeata*) has its teeth, which are four, fixed upon its proboscis, and is of course able to extend and retract them at pleasure; and the leech has three pointed cartilaginous teeth, which it is able to employ in the same way, and by means of which it draws blood freely. In like manner, though insects chiefly depend upon a serrated jaw, yet many of them are also possessed of very powerful fangs, of which we have a striking instance in the aranea *avicularia*, or bird-spider, an inhabitant of South America, found among trees, and a devourer of other insects and even small birds. It is of so enormous a size that its fangs are equal to the talons of a hawk; and its eyes, which are eight in number, arranged as a smaller square in the middle of a larger, are capable of being set in the manner of lenses, and used as microscopes.

In many animals, especially the herbivorous, the tongue itself is armed with a serrated apparatus, the papillæ being pointed and recurvated, and enabling them to tear up the grass with much greater facility. In the cat-kind the tongue is covered with sharp and strong prickles, which enable the animal to take a strong hold; and similar processes are met with in the bat and the opossum. In the lamprey and myxine families, the tongue itself is covered with teeth. In that grotesque and monstrous bird the toucan, whose

bill is nearly as large as its whole body, the tongue is lined with a bundle of feathers, of the use of which, however, we are totally ignorant, though it is probably an organ of taste.

In the crab and lobster tribes the teeth are placed in the stomach, the whole of which is a very singular organ. It is formed on a bony apparatus, and hence does not collapse when empty. The teeth are inserted into it round its lower aperture or pylorus: their surface is extremely hard, and their margin serrated or denticulated, so that nothing can pass through the opening without being perfectly comminuted. The bones and teeth are moved by peculiar muscles. It is a curious fact, that at the time the animal throws off its shell, it also disgorges its bony stomach and secretes a new one.

The teeth of the cuttle-fish are arranged not very differently, being situated in the centre of the lower part of the body; they are two in number, and horny, and in their figure exactly resemble the bill of a parrot.

The teeth of the echinus genus (sea-hedge-hog) are of a very singular arrangement. A round opening is left in the centre of the shell for the entrance of the food: a bony structure, in which five teeth are inserted, fills up this aperture; and as these parts are moveable by numerous muscles, they form a very complete organ of mastication.

Such is the variety which the hand of nature, sometimes, perhaps, sportive, but always skilful,

has introduced into the structure and arrangement of the teeth of animals, or the organs that are meant to supply their place.

The SKIN AND ITS APPENDAGES offer an equal diversity, and constitute the next subject of our enquiry.

All living bodies, whether animal or vegetable, are furnished with this integument: in all of them it is intended as a defence against the injuries to which, by their situation, they are commonly exposed; and in most of them it also answers the purpose of an emunctory organ, and throws off from the body a variety of fluids, which either serve by their odour to distinguish the individual, or are a recrement eliminated from its living materials.

This integument accompanies animals and vegetables from their first formation: it involves equally the seed and the egg; and possessing a nature less corruptible than the parts it incloses, often preserves them uninjured for many years, till they can meet with the proper soil or season for their healthy and perfect evolution.

This is a curious subject, and must not be too hastily passed over. After fish-ponds have been frozen to the very bottom, and all the fishes contained in them destroyed; or after they have been completely emptied, and cleared of their mud; eels and other fishes have been again found in them, though no attempt has been made to re-stock the ponds. Whence has proceeded this reproduction? Many of the

ancient schools of philosophy, and even some of those of more modern date, refer us to the doctrine of spontaneous generation, and believe that they have here a clear proof of its truth. But this is to account for a difficulty by involving ourselves in one of a much greater magnitude. It is a *petitio principii* which we stand in no need of, and which we should be careful how we concede. The reproduced fishes have alone arisen from the ova of those which formerly inhabited the fish-pond; and which, from some cause or other, had sunk so deep into the soil, as to be beyond the germinating influence of the warmth and air contained in the supernatant water, communicated to it by the sun and the atmosphere. But the indestructible texture of the integument which inclosed the fecundated ova has preserved them, perhaps for years, from injury and corruption; and they have only waited for that very exposure to light, air, and warmth, which the removal of the superior stratum of mud has produced, to awaken from their dormant state into life, form, and enjoyment; and but for which they would have remained in the same state, dormant but not destroyed, for ten or twelve times as long a period.

So, in the hollows upon our waste lands, when they have been for some time filled with stagnant water, we not unfrequently find eels, minows, and other small species of the carp genus; leeches * and water insects, and wonder

* See Wild. p. 120. note.

how they could get into such a situation. But the mud which has been emptied out of the preceding fish-pond has perhaps been thrown into these very hollows; or the ova of the animals have been carried into the same place by some more recondite cause; and they have been waiting, year after year, for the accidental circumstance which has at length arrived, and given them the full influence of warmth, water, light, and air.

The ova of many kinds are peculiarly light, and almost invisibly minute. They are hence, when the mud, which has been removed from fish-ponds, becomes dry and decomposed into powder, swept by the breeze into the atmosphere, from which they have occasionally descended into the large tanks which are made in India as reservoirs for rain-water; and producing their respective kinds in this situation, have appeared, to the astonishment of all beholders, to have fallen from the clouds with the rain itself. Dr. Thomson, in adverting to this curious fact, observes that it is difficult to account for it satisfactorily.* The explanation now offered will, if I mistake not, sufficiently meet the case.

Many insects can only be hatched in a particular animal organ; and it is the office of the integument of the ovum to preserve it in a perfect state till it has an opportunity of reaching its

* Annals of Philos. viii. p. 70.

proper nidus. Thus the horse-gadfly, or oestrus *equi*, deposits its eggs on the hairs of this animal, and sticks them to the hair-roots by a viscous matter which it secretes for this purpose. But here they could never be hatched, though they were to remain through the whole life of the horse: their proper nidus is the horse's stomach or intestines, and to this nidus they must be conveyed by some means or other; and in their first situation they must remain and be preserved, free from injury or corruption, till they can obtain such a conveyance. The integument in which they are wrapped up gives them the protection they stand in need of; and the itching which they excite in the horse's skin compels him to lick the itching part with his tongue; and by this simple contrivance the ova of the gadfly are at once conveyed to his mouth, and pass with the food into the very nidus which is designed for them.

It is the same integument that, by its incorruptibility, preserves the caterpillar during the torpitude of its chrysalid state, while suspended by a single thread from the eaves of an incumbent roof; and which thus enables the worm to become transformed into a butterfly. The larve of the gnat, when approaching the same defenceless state, dives boldly into the water, and is protected by the same indestructible sheath from the dangers of an untried element.

In several species the insect remains in its chrysalid state for many years: the locust, in

one of its species at least, the cicada *septendecim*, appears *in numbers* once only in seventeen years, and the palmer-worm once only in thirty years; cycles not recognised by the meteorologist, but which are well entitled to his attention: and, through the whole range of their duration, it is the integument we are now speaking of that furnishes the animal with a secure protection.

Whence comes it that plants of distant and opposite climates (for every climate has its indigenous plants as well as its indigenous animals) should so frequently meet together in the same region? that those which naturally belong to the Cape of Good Hope should be found wild in New Holland? and those of Africa on the coast of Norway? and that the Floras of every climate under the heavens should consociate in the stoves and gardens of our own country? It is the imperishable nature of the integument that surrounds their seeds by which this wonder is chiefly effected. Some of these seeds are provided with little hooks, and fasten themselves to the skins of animals, and are thus carried about from place to place; others adhere by a native glue to the feathers of water-fowls, and are washed off in distant seas; while a third sort are provided by nature with little downy wings, and hence rise into the atmosphere, and are blown about by the breezes towards every quarter of the compass. Of this last kind is the light seed of the betula *alba*, or birch-tree;

which, in consequence, is occasionally seen germinating on the summit of the loftiest rocks and the tops of the highest steeples.* But it is to man himself that this dissemination of plants is chiefly owing. He who in some sort commands nature — who changes the desert into a beautiful landscape — who lays waste whole countries, and restores them to their former fruitfulness — is the principal instrument of enriching one country with the botanical treasures of all the rest. Wars, migrations, and crusades, travel, curiosity, and commerce, have all contributed to store Europe with a multitude of foreign productions, and to transplant our own productions into foreign quarters. Almost all the culinary plants of England, and the greater number of our species of corn, have reached us from Italy or the East †; America has since added some; and it is possible that Australia may yet add a few more.

The utmost period of time to which seeds may hereby be kept, and be enabled to retain their vital principle, and consequently their power of germination, has not been accurately determined, but we have proofs enough to show that the duration may be very long. Thus, M. Triewald relates that a paper of melon-seeds, found in 1762, in a cabinet of Lord Mor-

* There is an interesting article on this subject published long since the above was delivered, an account of which may be found in the Journal of Science and the Arts, No. vii. p. 3.

† Wildenow, Principles, &c. § 357.

timer, and apparently collected in 1660, were then sown, and produced flowers and excellent fruit*; and Mr. R. Gale gives an instance of a like effect from similar seeds after having been kept thirty-three years.†

M. Saint-Hilaire sowed various seeds belonging to the collection of Bernard de Jussieu, forty-five years after the collection had been made. They consisted of three hundred and fifty distinct species; of these many, though not the whole, proved productive. In some the cotyledon appeared to have nearly, but not entirely, perished: in which, therefore, though the seeds swelled, and promised fairly at first, they died away gradually. And as it is a well-known fact that melons improve from seeds that have been kept for two or three years, he conceives that in this case the cotyledons have been ripened during such period.‡

Animal seeds or eggs, when perfectly impregnated, appear capable of preservation as long. Bomare, indeed, affirms, that he himself found three eggs, which, protected from the action of the air, had continued fresh in the wall of a church in which they must have remained for a period of *three hundred years*.§

The integument which covers seeds, eggs, insects, and worms, seldom consists of more than

* Phil. Trans. vol. xlii. † Id. vol. xliii.

‡ Tilloch's Phil. Mag. vol. xlii. p. 208. article of M. Saint Hilaire.

§ Dictionaire, art. Oeuf.

two distinct layers, and is sometimes only a single one; but in the four classes of red-blooded animals it consists almost uniformly of three layers, which are as follows: first, the true skin, which lies lowermost, is the basis of the whole, and may be regarded as the condensed external surface of the cellular substance, with nerves, blood-vessels, and absorbents interwoven in its texture; secondly, a mucous web (rete mucosum), which gives the different colours to the skin, but which can only be traced as a distinct layer in warm-blooded animals; and, thirdly, the cuticle, which covers the whole, and is furnished in the different classes with peculiar organs for the formation and excretion of a variety of ornamental or defensive materials—as hairs, feathers, wool, and silk.

The CUTIS, or TRUE SKIN, is seldom uniformly thick, even in the same animal: thus, in man, and other mammals, it is much thicker on the back than in the front of the body; but in the different classes or genera of animals it offers us every possible variety. Generally speaking, it is thinnest in birds, excepting in the duck tribe and in birds of prey. Its consistency and elasticity in horses, oxen, sheep, and other cattle, render it an object of high value, and lay a foundation for a variety of our most important trades and manufactures. In many animals it is so thick and tough, as to be proof against a musket-ball. It is sometimes found so in the elk, but usually so in the elephant, which, at the same

time, possesses the singularity of being sensible to the sting of flies. The skin of the rhinoceros despises equally the assault of swords, musket-balls, and arrows.

I have observed already, that in many animals the skin performs the office of a muscle, though it is seldom that any thing like a fibrous structure can be traced in it. The skin of man offers a few partial instances of this power, as in the forehead and about the neck. In most quadrupeds we trace the power extending over the whole body, and enabling them to throw off at their option insects and other small animals that irritate them. The skin of the horse shudders through every point of it at the sound of a whip, and is said to be generally convulsed on the appearance of a lion or tiger. Birds, and especially the cockatoo and heron tribes, derive hence a power of moving at pleasure the feathers of the crest, neck, and tail; and the hedgehog, of rolling himself into a ball, and erecting his bristles by way of defence.

The colour of the skin is derived from the RETE MUCOSUM, or MUCOUS WEB, which, as I have already remarked, is disposed between the true skin and the cuticle. The name of rete, or web, however, does not properly apply to this substance, for it has no vascularity, and is a mere butter-like material, which, when black, has a near resemblance in colour, as well as consistency, to the grease introduced between the nave of a wheel and its axletree. It is to this we owe

the beautiful red or violet that tinges the nose and hind-quarters of some baboons, and the exquisite silver that whitens the belly of the dolphin and other cetaceous fishes. In the toes and tarsal membrane of ravens and turkies it is frequently black; in hares and peacocks, grey; blue in the titmouse; green in the water-hen; yellow in the eagle; orange in the stork; and red in some species of scolopax or wood-cock. It gives that intermixture of colours which besprinkles the skin of the frog and salamander; but it is for the gay and glittering scales of fishes, the splendid metallic shells of beetles, and the gaudy eye-spots that bedrop the wings of the butterfly, that nature reserves the utmost force of this wonderful pigment, and sports with it in her happiest caprices.

The different colours, and shades of colours, of the human skin, are attributable to the same material. Most of these, however, are intimately connected with a very full access of solar light and heat; for a deep sun-burnt skin has a near approach to a mulatto.* And hence the darkness or blackness of the complexion has been generally supposed to proceed from the effect produced upon the mucous pigment by the solar rays, and especially those of the calorific kind, in consequence of their attracting and detaching the oxygene of the pigment in proportion to the abundance with which it impinges

* Humboldt, Essai Polit. sur la Nouvelle Espagne, &c.

against the animal surface, and, in the same proportion, setting at liberty the carbone, which is thus converted into a more or less perfect charcoal. As this, however, is a subject which I shall have occasion to revert to in a distinct study upon the varieties of the human race *, it is unnecessary to pursue it any farther at present.

It is a most curious circumstance, that the children of negroes are uniformly born white, or nearly so; and that the black pigment which colours them is not fully secreted till several months after birth. It sometimes happens, though rarely, that from a morbid state of the secretory organs there is no pigment secreted at all, or a white pigment is secerned instead of a black; whence we have white negroes, or persons exhibiting all the common characters of the negro breed in the form of the head and features of the face, with the anomaly of a white skin. And it sometimes happens, though still more rarely, that from a similar kind of morbid action affecting the secretory organs, the black pigment is secreted in alternate or interrupted divisions; and in this case we have negro children with brindled, marbled, or spotted skins: an instance of which was brought to me by a gentleman about two years ago, who had purchased the child in America, and who, I believe, afterwards exhibited it in this metropolis as a public show.

The CUTICLE is the thinnest of the layers that form the general integument of the skin. It

* Vol. II. Ser. II. Lect. III.

often, however, becomes thicker, and sometimes even horny, by use. Thus it is always thicker in the sole of the foot and palm of the hand; and horny in the palms of blacksmiths and dyers; and still more so in the soles of those who walk bare-footed on burning sands. It is annually thrown off whole by many tribes of animals — as grass-hoppers, serpents, and spiders — and as regularly renewed; and by some animals it is renewed still more frequently: it is shed not less than seven times by the caterpillar of the moth and butterfly before either becomes a chrysalis. There are a few plants that exfoliate their cuticle in the same manner, and as regularly renew it. The West India plane-tree throws it off annually.

From the cuticle shoots forth a variety of substances, which either protect or adorn it, the roots of which are not unfrequently imbedded in the true skin itself. Of the harder kind, and which serve chiefly as a defence, are the nails, scales, claws, and horns; of the softer and more ornamental kinds, are hair, wool, silk, and feathers.

Hair is the most common production, for we meet with it not only in all mammals, but occasionally in birds, fishes, and insects, varying in consistency and fineness, from a down invisible to the naked eye, to a bristle strong enough to support, when a foot long, ten or twelve pounds weight without breaking.

Wool is not essentially different in its chemical

properties from hair, and it varies equally in the fineness and coarseness of its texture. It is generally supposed by the growers, that the fineness of its texture depends upon the nature of the soil; yet of the two finest sorts we are at present acquainted with, that of Spain and that of New South Wales, which last is an offset from the Cape of Good Hope, and has yielded specimens of broad cloth, manufactured in this country, as soft and silky as that of unmixed Merino wool—that of Spain is grown on a pure limestone soil, covered with small leguminous plants instead of with grass; and that of New South Wales on a soil totally destitute of lime, and covered with a long, rich, succulent grass alone.

Food, however, or climate, or both, must be allowed, under certain circumstances, to possess a considerable degree of influence; for it is a curious fact, that the hair of the goat and rabbit tribes, and the wool of the sheep tribe, are equally converted into silk by a residence of these animals in that district of Asia Minor which is called Angora, though we do not know that a similar change is produced by a residence in any other region; while, on the contrary, the wool of sheep is transformed into hair on the coast of Guinea.

The fine glossy SILK of the Angora goat is well known in this country, as being often employed for muffs and other articles of dress. How far these animals might be made to perpetuate this peculiar habit by a removal from Angora to

other countries has never yet been tried. Upon the whole, the soil and climate of New Holland offer the fairest prospect of success to such an attempt; and under this impression I have for some time been engaged in an endeavour to export a few of each genus of these animals from Angora to Port Jackson.

Silk, however, is chiefly secreted by insects, as some species of spider, whose threads, like the hair of the Angora goat, assume a silky gloss and lubricity, and the phalæna *mori*, or silk-worm, which yields it in great abundance. Yet there are a few shell-fishes which generate the same, and especially the genus pinna, or nacre, in all its species; whence Reaumur calls this kind the sea silk-worm. It is produced in the form of an ornamental byssus or beard; the animal is found gregariously in the Mediterranean and Indian seas; and the weavers of Palermo manufacture its soft threads into glossy stuffs or other silky textures. And I may here observe, that there are various trees that possess a like material in the fibres of their bark, as the morus *papyrifera*, and several other species of the mulberry: in consequence of which it has been doubted by some naturalists whether the silk-worm actually generates its cocoon, or merely eliminates it from the supply received as its food; but as the silk-worm forms it from whatever plants it feeds on, it is obviously an original secretion.

From the integument of the skin originates

also that beautiful PLUMAGE which peculiarly characterises the class of birds, and the colours of which are probably a result of the same delicate pigment that produces, as we have already remarked, the varying colours of the skin itself; though, from the minuteness with which it is employed, the hand of chemistry has not been able to separate it from the exquisitely fine membrane in which it is involved. But it is impossible to follow up this ornamental attire through all its wonderful features of graceful curve and irridescent colouring, — of downy delicacy and majestic strength, — from the tiny rainbow that plays on the neck of the humming-bird, to the beds of azure, emerald, and hyacinth, that tesselate the wings of the parrot tribe, or the ever-shifting eyes that dazzle in the tail of the peacock; — from the splendour and taper elegance of the feathers of the bird of paradise, to the giant quills of the crested eagle or the condur — that crested eagle, which in size is as large as a sheep, and is said to be able to cleave a man's scull at a stroke; and that condur which, extending its enormous wings to a range of sixteen feet in length, has been known to fly off with children of ten or twelve years of age.

Why have not these monsters of the sky been appropriated to the use of man? How comes it that he who has subdued the ocean and cultivated the earth; who has harnessed elephants, and even lions, to his chariot wheels; should never have availed himself of the wings of the

eagle, the vulture, or the frigate pelecan? That, having conquered the difficulty of ascending into the atmosphere, and ascertained the possibility of travelling at the rate of eighty miles an hour through its void regions, he should yet allow himself to be the mere sport of the whirlwind, and not tame to his use, and harness to his car, the winged strength of these aerial racers, and thus stamp with reality some of the boldest fictions of the heathen poets? The hint has indeed long been thrown out; and the perfection to which the art of falconry was carried in former times, sufficiently secures it against the charge of absurdity or extravagance.

LECTURE XII.

ON THE DIGESTIVE FUNCTION AND THE ORGANS CONTRIBUTORY TO IT: THE DIFFERENT KINDS OF FOOD EMPLOYED BY DIFFERENT ANIMALS: CONTINUANCE OF LIFE THROUGH LONG PERIODS OF FASTING.

UNDER every visible form and modification matter is perpetually changing: — not necessarily so, or from its intrinsic nature; for the best schools of ancient times concur with the best schools of modern times, in holding its elementary principles, as I have already observed, to be solid and unchangeable; and we have still further seen, that, even in some of its compound, but gasseous, etherialized, and invisible forms, it is probably alike exempted from the law of change; while the christian looks forward with holy hope to a period when this exemption will be general, and extend to every part and to every compound; to a period in which there will be new heavens and a new earth, and what is now corruptible will put on incorruption.

At present, however, we can only contemplate matter, under every visible form and modification, as perpetually changing; as living

dying, and reviving; decomposing into its primordial elements, and recombining into new forms, and energies, and modes of existence. The germ becomes a seed, the seed a sapling, the sapling a tree: the embryo becomes an infant, the infant a youth, the youth a man; and having thus ascended the scale of maturity, both instantly begin the downward path to decay; and, so far as relates to the visible materials of which they consist, both at length moulder into one common elementary mass, and furnish fresh fuel for fresh generations of animal or vegetable existence. So that all is in motion, all is striving to burst the bonds of its present state; not an atom is idle; and the frugal economy of nature makes one set of materials answer the purpose of many, and moulds it into every diversified figure of being, and beauty, and happiness.

But till the allotted term of existence has arrived, animals and vegetables are rendered equally capable of counteracting the waste they are perpetually sustaining in their individual frames; and are wisely and benevolently endowed with organs, whose immediate function it is to prepare a supply of reformative and vital matter adequate to the general demand.

Of this class of organs in plants we took a brief survey in our eighth lecture; and shall now proceed to notice the same class as it exists in animals, and which is generally distinguished by the name of the DIGESTIVE SYSTEM.

There is, perhaps, no animal function that displays a larger diversity of means by which it is performed than the present: and, perhaps, the only point in which all animals agree is in the possession of an internal canal or cavity of some kind or other in which the food is digested; an agreement which may be regarded as one of the leading features by which the animal structure is distinguished from the vegetable.

Let us then, in the first place, trace this cavity as it exists in man, and the more perfect animals; the organs which are supposed to be auxiliary to it, and the powers by which it accomplishes its important trust. Let us next observe the more curious deviations and substitutes that occur in classes that are differently formed: and lastly, let us attend to a few of the more singular anomalies that are occasionally met with, and especially in animals that are capable of subsisting on air or water alone, or of enduring very long abstinences or privations of food.

The alimentary cavity in man extends from the mouth through the whole range of the intestinal canal *: and hence its different parts are of very different diameters. In the mouth, where it commences, it is wider; it contracts in the esophagus or gullet; then again widens to form the stomach, and afterwards again contracts into the tube of the intestines. This tube itself is also of different diameters in different parts of its extent; and it is chiefly on this

* Stud. of Med. ii. 2.

diversity of magnitude, that anatomists have established its divisions. Its general length is five or six times that of the man himself; and in children not less than ten or twelve times, in consequence of their diminutive stature. In some animals it is imperforate; it is so occasionally in birds, and fishes, and almost uniformly so in zoophytes.

Generally speaking, the extent of the digestive cavity bears a relation to the nature of the aliments by which the individual is designed to be nourished. The less analogous these aliments are to the substance of the animal they are to sustain, the longer they must remain in the body to undergo the changes that are necessary to assimilate them. Hence the intestinal tube of herbivorous animals is very long, and their stomach is extremely large, and often double or triple; whilst the carnivorous have a short and straight digestive canal, the food on which they feed being already of their own nature, and containing a larger quantity of nourishment in a less bulk; and hence demanding a smaller proportion both of time and space to become fit for use. In this respect man holds a medium between the two; his digestive canal is less complex than that of most animals that feed on grass alone, and more extensive than that of most animals that are confined to a diet of their own kind. Man is hence omnivorous, and is capable of subsisting on an aliment of either sort: and from his digestive organs, as

well as from various others, is better qualified for every variety of soil and climate than any other animal.

Man, however, is by no means the only omnivorous animal in the world; for the great author of nature is perpetually showing us that though he operates by general laws, he is in every instance the lord and not the slave of them. Hence, among quadrupeds, the swine, and among insects, the ant, possesses as omnivorous a power as man himself, and feeds equally on the fleshy parts of animals, and on grain, and the sweet juices of vegetables. In consequence of this omnivorous power in the ant, we may often make use of him as a skilful anatomist; for, by putting a dead frog, mouse, or other small animal in a box perforated with holes, and placing it near an ant-hill, we shall find it in a few days reduced to a perfect and exquisite skeleton, every atom of the soft parts being separated and devoured.

The solid materials of the food are first masticated and moistened in the mouth, excepting in a few cases, in which it is swallowed whole. It is then introduced into the stomach, and converted into an homogeneous pulp or paste, which is called chyme; and shortly afterwards, by an additional process, into a fluid for the most part of a milky appearance, denominated chyle; in which state it is absorbed or drunk up voraciously by thousands, and tens of thousands of little mouths of very minute vessels, which

are not often found in the stomach, but line the whole of the interior coating of that part of the intestinal tube into which the stomach immediately empties itself, and which are perpetually waiting to imbibe its liquid contents. These vessels constitute a distinct part of the lymphatic system; they are called lacteals from the usual milky appearance of the liquid they absorb and contain. They progressively anastomose or unite together, and at length terminate in one common trunk, named the thoracic duct, which conveys the different streams thus collected and aggregated to the sanguineous system, to be still farther operated upon, and elaborated by the action of the heart and the lungs.

The means by which the food is broken down and rendered pultaceous after being received into the stomach are various and complicated. In the first place, the muscular tunic of the stomach acts upon it by a slight contraction of its fibres, and so far produces a mechanical resolution: secondly, the high temperature maintained in the stomach by the quantity of blood contained in the neighbouring viscera and sanguiferous vessels, gives it the benefit of accumulated heat, and so far produces a concoctive resolution: and thirdly, the stomach itself secretes and pours forth from the mouths of its minute arteries a very powerful solvent, which is by far the chief agent in the process, and thus produces a chemical resolution. In this manner the moistened and manducated food becomes

converted into the pasty mass we have already called chyme: and fourthly, there are a variety of juices separated from the mass of the blood by distinct glands situated for this purpose in its vicinity, which are thrown into the duodenum, or that part of the canal into which the stomach immediately opens, by particular conduits, and in some way or other appear to contribute to the common result, and to transform the chyme into chyle, but concerning the immediate powers or modes of action of which we are in a considerable degree of darkness. Of these glands the most remarkable and the most general are the liver and the pancreas or sweet-bread; the first of which secretes the bile, and is always of a considerable size, and appears to produce a very striking effect on the blood itself, by a removal of several of its principles, independently of its office as a digestive organ.

From this brief survey of the process of digestion it is obvious that the stomach itself performs by far the principal part; in some animals indeed it appears to perform the whole; and it is hence necessary that we examine the general structure and powers of this organ with a little more minuteness.

In man the stomach is situated on the left side of the midriff; in its figure it resembles the pouch of a bag-pipe; its left end is most capacious; its upper side is concave, its lower convex; and the two orifices for receiving and discharging the food are both situated in the

upper part. In its substance it consists of three distinct coats or layers, the external and internal of which are membranous, and the middle muscular. The internal coat, moreover, is lined with a villous or downy apparatus, and is extrêmely convoluted or wrinkled; the wrinkles increasing in size as the diameter of the stomach contracts.

From what I have already observed it must appear that the process of digestion in man consists of three distinct acts: mastication, which is the office of the mouth, and by which the food is first broken down; chymification, or its reduction into pulp, which is the office of the stomach; and chylification, or its dilution into a fluid state, which is the office of that part of the intestinal canal which immediately communicates with the stomach. The whole of this process is completed in about three hours, and under certain states of the stomach, to which I shall advert presently, almost as quickly as the food is swallowed. The most important of these three actions is that of chymification; and, while it takes place, both orifices of the stomach are closed, and a degree of chilliness is often produced in the system generally, from the demand which the stomach makes upon it for an auxiliary supply of heat, without an augmentation of which it appears incapable of performing this important function.

Considering the comparatively slender texture of the chief digesting organ, and the toughness

and the solidity of the substances it digests, it cannot appear surprising that mankind should have run into a variety of mistaken theories in accounting for its mode of action. Empedocles and Hippocrates supposed the food to be softened by a kind of putrefaction. Galen, whose doctrine descended to recent times, and was zealously supported by Grew and Santarelli, ascribed the effect to concoction, produced, like the ripening and softening of fruits beneath a summer sun, by the high temperature of the stomach from causes just pointed out. Pringle and Macbride advocated the doctrine of fermentation, thus uniting the two causes of heat and putrefaction assigned by the Greek writers; while Borelli, Keil, and Pitcairn resolved the entire process into mechanical action, or trituration; thus making the muscular coating of the stomach an enormous mill-stone, which Dr. Pitcairn was extravagant enough to conceive ground down the food with a pressure equal to a weight of not less than a hundred and seventeen thousand and eighty pounds, assisted at the same time, in its gigantic labour, by an equal pressure derived from the surrounding muscles. *

Each of these hypotheses, however, was encumbered with insuperable objections; and it is difficult to say which of them was most incompetent to explain the fact for which they were invented.

Boerhaave endeavoured to give them force by interunion, and hence combined the mechanical

* See Vol. I. Ser. I. Lect. X.

theory of pressure with the chemical theory of concoction; while Haller contended for the process of maceration. But still a something else was found wanting, and continued to be so till Cheselden in lucky hour threw out the hint, for at first it was nothing more than a hint, of a menstruum secreted into some part of the digestive system; a hint which was soon eagerly laid hold of, and successfully followed up by Haller, Reaumur, Spallanzani, and other celebrated physiologists. And though Cheselden was mistaken in the peculiar fluid to which he ascribed the solvent energy, namely the saliva, still he led forward to the important fact, and the GASTRIC JUICE was soon afterwards clearly detected, and its power incontrovertibly established.

This wonderful menstruum, the most active we are acquainted with in nature, is secreted by a distinct set of vessels that exist in the texture of the stomach, and empty themselves into its cavity by innumerable orifices invisible to the naked eye; and it is hence called gastric juice, from γαστὴρ, which is Greek for stomach. Mr. Cruickshank supposes about a pound of it to be poured forth every twenty-four hours. "The drink," says he, "taken into the stomach may be two pounds in twenty-four hours; the saliva swallowed may be one pound in the same period, the gastric juice another, the pancreatic juice another. The bile poured into the intestines Haller supposes about twenty ounces,

besides the fluid secreted through the whole of the internal surfaces of the intestines * ;" which Haller calculates at not less than eight pounds in twenty-four hours,—a calculation nevertheless that Blumenbach regards as extravagant. †

The quantity of the gastric juiçe, however, seems to vary very considerably, according to the demand of the system generally, or the state of the stomach itself. In carnivorous birds, whose stomachs are membranous alone, and consequently whose food is chymified by the sole action of the gastric juice, without any collateral assistance or previous mastication, this fluid is secreted in much larger abundance; as it is also in those who labour under that morbid state of the stomach which is called canine appetite; or when, on recovery from fevers, or in consequence of long abstinence, the system is reduced to a state of great exhaustion, and a keen sense of hunger induces a desire to devour food voraciously and almost perpetually.

Such was the situation of Admiral Byron and his two friends Captains Cheap and Hamilton, after they had been shipwrecked on the western coast of South America, and had been emaciated, as he tells us, to skin and bone, by having suffered with hunger and fatigue for some months. "The governor," says Admiral Byron, "ordered a table to be spread for us with cold ham and fowls,

* Anat. of the Absorbing Vessels, p. 106.

† Physiol. Institut. xxvii. § 410.

which only we three sat down to, and in a short time despatched more than ten men with common appetites would have done. It is amazing that our eating to that excess we had done from the time we first got among these kind Indians had not killed us; we were never satisfied, and used to take all opportunities, for some months after, of filling our pockets when we were not seen, that we might get up two or three times in the night to cram ourselves." *

When pure and in a healthy state, the gastric juice is a thin, transparent, and uninflammable fluid, of a weak saline taste, and destitute of smell. Generally speaking it is neither acid nor alkaline; but it appears to vary more or less in these properties, not only in animals whose organs of digestion are of a different structure, but even in the very same animal under different circumstances. It may, however, be laid down as an established rule, that in *carnivorous* and *graminivorous* animals possessing only a single stomach, this fluid is acid, and colours blue vegetable juices red; in *omnivorous* animals, as man, whose food is composed both of vegetable and animal diet, it is neutral; and in graminivorous *ruminating* animals with four stomachs, and particularly in the adults of these tribes, it has an alkaline tendency, and colours blue vegetable juices green.

* Voyage, p. 181. See also Hunter's Animal Economy, p. 196.

There are two grand characteristics by which this fluid is pre-eminently distinguished; a most astonishing faculty of counteracting and even correcting putrefaction; and a faculty, equally astonishing, of dissolving the toughest and most rigid substances in nature.

Of its ANTISEPTIC POWER abundant proofs may be adduced from every class of animals. Among mankind, and especially in civilized life, the food is usually eaten in a state of sweetness and freshness; but fashion, and the luxurious desire of having it softened and mellowed to our hands, tempt us to keep several kinds as long as we can endure the smell. The wandering hordes of gypsies, however, and the inhabitants of various savage countries, and especially those about the mouth of the Orange river in Africa, carry this sort of luxury to a much higher pitch, for they have no objection to an offensive smell, and appear to value their food in proportion to its approach towards putrefaction. Now all these foods, whatever be the degree of their putridity, are equally restored to a state of sweetness by the action of this juice, a short time after they have been introduced into the stomach.

Dr. Fordyce made a variety of experiments in reference to this subject upon the dog, and found uniformly that the most putrid meat he could be made to swallow, was in a very short time deprived of its putrescency. We cannot therefore be surprised that crows, vultures, and hyenas, who find a pleasure in tainted flesh,

should fatten upon so impure a diet; nor that the dunghill should have its courtiers among insects as well as the flower-garden.

The gastric juice has hence been employed as an antiseptic in a variety of cases out of the body.

Spalanzani has ascertained that the gastric juice of the crow and the dog will preserve veal and mutton perfectly sweet, and without consumption, thirty-seven days in winter; whilst the same meats immersed in water emit a fetid smell as early as the seventh day, and by the thirtieth are resolved into a state of most offensive liquidity.

Physicians and surgeons have equally availed themselves of this corrective quality, and have occasionally employed the gastric juice, internally in cases of indigestion from a debilitated stomach, and externally as a check to gangrenes, and a stimulus to impotent and indolent ulcers. I do not know that this practice has hitherto taken place very largely in our own country, but it has been extensively resorted to on the continent, and especially in Switzerland and Italy; and in many cases with great success.

But the gastric juice is as remarkable for its solvent, as for its antiputrescent property. Of this any industrious observer may satisfy himself by attending to the process of digestion in many of our most common animals; but it has been most strikingly exemplified in the experiments of Reaumur and Spalanzani. Pieces of the

toughest meats, and of the most solid bones, inclosed in small perforated tin-cases to guard against all muscular action, have been repeatedly thrust into the stomach of a buzzard: the meats were uniformly found diminished to three fourths of their bulk in the space of twenty-four hours, and reduced to slender threads; and the bones were wholly digested, either upon the first trial or a few repetitions of it. Dr. Stevens repeated the experiment on the human stomach by means of a perforated ivory ball, which he hired a person at Edinburgh alternately to swallow and disgorge, when a like effect was observed.

The gastric juice of the dog dissolves ivory itself and the enamel of the teeth; that of the hen has dissolved an onyx and diminished a louis d'or *; even among insects we find some tribes that fatten upon the fibrous parts of the roots of trees, and others upon metallic oxydes. And it is not long since that, upon examining the stomach and intestinal tube of a man who died in one of the public hospitals of this metropolis, and who had some years before swallowed a number of clasp-knives out of hardihood, their handles were found digested, and their blades blunted, though he had not been able to discharge them from his body.

It is in consequence of this wonderful power that the stomach is sometimes found in the extra-

* Swammerdam, Biblia Naturæ, p. 168.

ordinary condition of digesting itself; and of exhibiting, when examined on dissection, various erosions in different parts of it, and especially towards the upper half, into which the gastric juice is supposed to flow most freely. It is the opinion of Mr. John Hunter *, however, whose opinions are always entitled to respect, that such a fact can never take place except in cases of sudden death, when the stomach is in full health, and the gastric juice, now just poured forth, is surrounded by a dead organ. For he plausibly argues, that the moment the stomach begins to be diseased, it ceases to secrete this fluid, at least in a state of perfect activity; and that so long as it is itself alive, it is capable by its living principle of counteracting the effect of this solvent power. Yet a case has lately been published by Mr. Burns of Glasgow, in which the stomach appears to have been eroded, although the death, instead of being sudden, did not take place till after a long illness and great emaciation of the body. It is possible, however, that even here the stomach did not participate in the disease. That the living principle of the stomach is capable, so long as it continues in the stomach, of resisting the action of the gastric juice, can hardly be questioned. And it is to the superior power of this principle of life, that worms and the ova of insects are so often capable of existing in the stomach uninjured,

* Phil Trans. 1772

and even of thriving in the midst of so destructible an agency.

But though the solvent juice of the stomach is the chief agent in the process of digestion, its muscular power contributes always something, and in many animals a considerable proportion, towards the general result; and hence, the shape and structure of this organ, instead of being uniformly alike, is varied with the most skilful attention to the nature of the mechanism by which it is to operate.

In its general construction the stomach of different animals may be divided into three kinds; membranous, muscular, and bony. The first is common to graminivorous quadrupeds, and to carnivorous animals of most kinds; to sheep, oxen, horses, dogs, and cats; eagles, falcons, snakes, frogs, newts, and the greater number of fishes, as well as to man himself. The second is common to graminivorous birds; and to granivorous animals of most kinds; to fowls, ducks, turkies, geese, and pigeons. The third, to a few apterous insects, a few soft-bodied worms, and a few zoophytes; to the cancer-genus, the cuttle-fish, the sea-hedgehog; tubipores and madrepores.

Of the membranous stomach we have already taken notice in describing that of man; and at the bony stomach we took a glance in a late lecture on the teeth and other masticatory organs. It only remains, therefore, that we make a few remarks on that singular variety of the membranous stomach which belongs to

ruminant animals, and on the muscular stomach of granivorous and graminivorous birds.

All animals which ruminate must have more stomachs or ventricles than one; some have two, some three; and the sheep and ox not less than four. The food is carried down directly into the first, which lies upon the left side, and is the largest of all; the vulgar name for this is the *paunch*. There are no wrinkles on its internal surface; but the food is considerably macerated in it by the force of its muscular coat, and the digestive secretions which are poured into it. Yet, in consequence of the vegetable and unanalogous nature of the food, it requires a much farther comminution; and is hence forced up by the esophagus into the mouth, and a second time masticated; and this constitutes the act called rumination, or chewing the cud. After this process, it is sent down into the second ventricle, for the esophagus opens equally into both, and the animal has a power of directing it to which soever it pleases. This ventricle is called the *bonnet* or *king's-hood*; its internal surface contains a number of cells, and resembles a honey-comb; it macerates the food still farther; which is then protruded into the third ventricle, that on account of its very numerous folds or wrinkles, is called *many-plies*, and vulgarly *many-plus*. It is here still farther elaborated, and is then sent into the fourth ventricle, which, on account of its colour, is called *the red*, and by the French *le caillé*, or the curdle,

since it is here that the milk sucked by calves first assumes a curdled appearance. It is thus that the process of digestion is completed, and it is this compartment that constitutes the true stomach, to which the others are only vestibules.

There are some animals, however, which do not ruminate that have more than one stomach; thus the hampster has two, the kangaroo three, and the sloth not less than four.* Nor does the conformation terminate even with quadrupeds; for among birds the ostrich has two ventricles†, and among fishes the stomateus *Hiatola*. The horse and ass, on the contrary, though graminivorous quadrupeds like the ox, have only one stomach.

There may seem, perhaps, something playful in this application of different systems of mechanism to the same class of animals, and of the same system to different classes: but it shows us, at least, that the hand of nature is not necessarily fettered by its own general laws, nor compelled, even under the same circumstances, to adopt the same cause to produce the same effect. Yet, if we had time, we might proceed beyond this remark, and point out, if I mistake not, the reasons for such diversities, and the skill with which they are introduced. Thus the horse and ass are formed for activity, and require lightness; and hence the bulk and complexity of

* Wiedemann, Archiv. b. i.

† Valisnieri, Anatomia, &c. p. 159. 1713

three or four stomachs would counteract the object for which they are created; but it does not interfere with the pursuits of the ox, which is heavy and indolent in its nature; and which, though it may perhaps be employed as a beast of burden, can never be made use of for speed. The activity of the horse and ass, moreover, excites, from the stimulus it produces, a larger secretion of gastric juice than is met with in the ox, and thus in a considerable degree supplies a substitute for the three deficient stomachs; but it by no means extracts the nutriment so entirely from the food introduced into it; and we hence see the reason why the dung of horses is richer than that of black cattle, and why they require three or four times as much provender.

We may apply the whole of these remarks to the ostrich, whose peculiar habitation is the sandy and burning deserts of the torrid zone, where not a blade of grass is to be seen for hundreds of miles, and where the little food it lights upon must be made the most of. The double stomach it possesses enables it to accomplish this purpose, and to digest coarse grass, prickly shrubs, and scattered pieces of leather, with equal ease. This animal is supposed to be one of the most stupid in nature, and to have no discernment in the choice of its food; for it swallows stone, glass, iron, and whatever else comes in its way, along with its proper sustenance. But it is easy to redeem the ostrich from such a reproach, at least in the instance

before us: for these very articles, by their hard and indestructible property, perform the office of teeth in the animal's stomach; they enable it to triturate its food most minutely, and to extract its last particle of nutriment. It is true that in the class of birds, or that to which the ostrich belongs, a double stomach must necessarily, to a certain extent, oppose the general levity by which this class is usually characterised. But the wings of the ostrich are not designed for flight: they assist him in that rapidity of running for which he is so celebrated, and in which he exceeds all other animals, but are not designed to lift him from the earth. In reality, the ostrich appears to be the connecting link between birds and quadrupeds, and especially ruminant quadrupeds. In its general portrait, as well as in the structure of its stomach, it has a near resemblance to the camel; in its voice, instead of a whistle, it has a grunt, like that of the hog; in its disposition, it is as easily tamed as the horse, and like him may be employed, and often has been, as a racer, though in speed it outstrips the swiftest race-horse in the world. Adanson asserts, indeed, that it will do so when made to carry double; and that, when at the factory of Podore, he had two ostriches carefully broken in, the strongest of which, though young, would run swifter, with two negroes on his back, than a racer of the best breed.

Yet widely different is the mechanism of the

stomach in birds of flight that feed on vegetables: nor could any contrivance be better adapted to unite the two characters of strength and levity. Instead of the bulky and complicated compartments of the membranous stomach of ruminant animals, we here meet with a thick, tough, muscular texture, small in size, but more powerful than the stoutest jaw-bone, and which is usually called GIZZARD.

It consists of four distinct muscles, a large hemispherical pair at the sides, and two smaller muscles at the two ends of the cavity. These muscles are distinguished from the rest belonging to the animal, not less by their colour than by their prodigious strength; and the internal cuticle with which they are covered is peculiarly callous, and often becomes quite horny from pressure and friction.

The gizzard of grazing birds, as the goose and turkey, differs in some degree in the formation of its muscles from that of granivorous. They have also "a swell in the lower part of the esophagus, which answers the purpose of a reservoir, in which the grass is retained, macerated, and mixed with the secretions poured out by the glandular surfaces surrounding it, in this respect corresponding to the first and second stomachs of ruminating animals, in which the grass is prepared for mastication*," though essentially lighter.

* Home, On the Gizzards of Grazing Birds, Phil. Trans. 1810, p. 183.

In most birds, indeed, we meet with an approach towards this, in a cavity situated above the muscular stomach, and called the crop, or craw. This first receives the food from the mouth, and slighty softens it by a mucous fluid secreted from its interior; and thus prepared, a part of it is given back to the young, where there are young to partake of it, and the rest is sent to the gizzard or proper stomach, whose muscular mechanism, in conjunction with its gastric juice, soon comminutes it into the most impalpable pulp. There are several kinds, however, that, like the ostrich, endeavour to assist the muscular action by swallowing pebbles or gravel; some of which find this additional aid so indispensable, that they are not able to digest their food, and grow lean, without it. Spalanzani attempted to prove that these stones are of no use, and are only swallowed by accident; but their real advantage has been completely established by Mr. J. Hunter, who has correctly observed, that the larger the gizzards, the larger are the pebbles found in them. In the gizzard of a turkey he counted two hundred; in that of a goose, a thousand.

Reaumur and Spalanzani have put the prodigious power of this muscular stomach to the test, by compelling geese and other birds to swallow needles, lancets, and other hard and pointed substances; which, in every experiment, were found, a few hours afterwards, on killing

and examining the animal, or on its regorging them, to be broken off and blunted, without any injury to the stomach whatever.

Yet, as all animals are not designed for all kinds of food, neither the force of the strongest muscular fibres, nor the solvent power of the most active gastric juice, will avail in every instance. The wild-boar and the vulture devour the rattle-snake uninjured, and fatten upon it; but there are many kinds of vegetables which neither of these are capable of digesting. The owl digests flesh and bone, but cannot be made to digest grain or bread; and in one instance died, under the experiments of Spalanzani, when confined to vegetable food. The falcon seems as little capable of dissolving vegetables; yet the eagle dissolves bread and bone equally; and wood-pigeons may, in like manner, be brought to live, and even to thrive, on flesh-meat. The procellaria *pelagica*, or stormy petrel, lives entirely on oil, as the fat of dead whales and other fishes, whenever he can get it; and if not, converts every thing he swallows into oil. He discharges pure oil from his mouth at objects that offend him; and feeds his young with the same substance. This is the most daring of all birds in a tempest, though not more than six inches long. As soon as the clouds begin to collect, he quits his rocky covert, and enjoys the gathering and magnificent scenery: he rides triumphantly on the whirl-

wind, and skims with incredible velocity the giddiest peaks, and deepest hollows of the most tremendous waves. His appearance is a sure presage of foul weather to the seaman.

There are some tribes of animals that appear capable of subsisting on water alone, and a few on mere air, incapable as these substances seem to be, at first sight, of affording any thing like solid nutriment. Leeches and tadpoles present us with familiar proofs of the former assertion, and there are various kinds of fishes that may be added to the catalogue. Rondelet kept a silver fish in pure water alone for three years; and at the end of that period it had grown as large as the glass globe that contained it. Several species of the carp kind, and especially the gold-fish, have a similar power; and even the pike, the most gluttonous, perhaps, of the whole class, will both live and thrive upon water alone in a marble bason.

The bee, and various other insects, derive their nutriment from the nectar and effluvium of flowers. So also does the trochilus genus, or humming-bird, which appears to be the connecting link between the two classes; buzzing like the bee itself with a joyous hum around the blossom on which it lights; and in one of its species, *t. minimus*, not exceeding it in size, and only weighing from 20 to 45 grains.

Air alone appears sufficient for the support of animals of other kinds. Snails and chameleons

have been known repeatedly to live upon nothing else for years.* Garman asserts that it is a sufficient food for spiders; and that though they will devour other food, as fishes will that may be maintained alone on water, they do not stand in need of any other. Latreille confirms this assertion to a considerable extent, by informing us that he stuck a spider to a piece of cork, and precluded it from communication with any thing else for four successive months, at the end of which time it appeared to be as lively as ever.† And Mr. Baker tells us, in the Philosophical Transactions, that he had a beetle that lived in a glass confinement for three years without food, and then fled away by accident.

The larves of ants, as well as of several other insects of prey, are not only supported by air, but actually increase in bulk, and undergo their metamorphoses without any other nourishment. It is probable, also, that air is at times the only food of the scolopendra *phosphorea*, or luminous centipede, which has been seen illuminating the atmosphere, and sometimes falling into a ship, a thousand miles from land.

Amphibious animals have a peculiar tenacity to life under every circumstance of privation; and not only frogs, and toads, but tortoises, lizards, and serpents, are well known to have

* Encyclop. Brit. art. Physiol. p. 679.

† Monthly Rev. Appx. lv. 494.

existed for months, and even years, without other food than water — in some instances, without other food than air.

Mr. Bruce kept two cerastes, or horned snakes, in a glass jar for two years, without giving them any thing. He did not observe that they slept in the winter-season; and they cast their skins, as usual, on the last day of April.*

Lizards, and especially the newt species, have been found embedded in a chalk-rock, apparently dead and fossilized, but have re-assumed living action on exposure to the atmosphere.† On their detection in this state the mouth is usually closed with a glutinous substance, and closed so tenaciously, that they often die of suffocation in the very effort to extricate themselves from this material.‡

In respect to toads the same fact has been ascertained, for nearly two years, by way of experiment §; and has been verified, by accident, for a much longer term of time. The late Edward Walker, Esq. of Guestingthorpe, Essex, informed me not long since, that he had found a toad perfectly alive in the midst of a full grown elm, after it was cut down by his order, exactly

* Voyages, Appendix, p. 296. 8vo. edit.

† Wilkinson, Tilloch's Phil. Mag. Dec. 1816.

‡ Journ. of Science, No. XII. p. 375.

§ See Dalyell's Introd. to his Translation of Spalanzani's Tracts, p. xliii. 1803.

occupying the cavity which it appeared gradually to have scooped out as it grew in size, and which had not the smallest external communication by any aperture that could be traced. And very explicit, and apparently very cautious, accounts have been repeatedly published in different journals, of their having been found alive, imbedded in the very middle of trunks of trees and blocks of marble, so large and massy, that, if the accounts be true, they must have been in such situations for at least a century.* There is a very particular case of this kind given by M. Seigue, in the Memoirs of the Royal Academy of Paris. †

These observations lead us to another anomaly of a more extraordinary nature still; and that is, the power which man himself possesses of existing without food, under certain circum-

* See various instances, Encycl. Brit. art. Physiol. p. 681.

† Mem. 1731. H. 24. Dr. Edwards, of Paris, has sufficiently ascertained of late, that blocks of mortar, and heaps of sand, are porous enough to admit so much air as is requisite to support the life of lizards, toads, and other amphibials of the batrachian family: but that they all perish if surrounded by mercury, or even water, so as to intercept the air by their being encompassed by an exhausted receiver. In boxes of mortar or sand, however, they live much longer than in boxes plunged under water. The probable cause is, that the air of the atmosphere pervades the pores of the sand or margin pretty freely; but that it is not extricated from the circumfluent water so as to pervade the pores of the box buried in it. This however is not the explanation offered by Dr. Edwards. He found also that frogs will live a longer or shorter period of time under water, according to the temperature of the

stances, for a very long period of time. This is often found to take place in cases of madness, especially that of the melancholy kind, in which the patient resolutely refuses either to eat or drink for many weeks together, with little apparent loss either of bulk or strength.

There is a singular history of Cicely de Ridgeway, preserved among the Records in the Tower of London, which states, that in the reign of Edward III., having been condemned for the murder of her husband, she remained for forty days without either food or drink. This was ascribed to a miracle, and the king condescended in consequence to grant a pardon.

The Cambridgeshire farmer's wife, who, about twenty years ago, was buried under a snow-storm, continued ten or twelve days without tasting any thing but a little of the snow which covered her. But in various other cases we have proofs of abstinence from food having been carried much farther, and without serious evil. In the

water, and the previous temperature of the surrounding atmosphere. They die speedily if the water be lower than 32° Fahr. or higher than 108°: that the longest duration of life is at 32°, at which point life will continue for several hours; that its duration diminishes with the elevation of the scale above this point, and that it is extinguished in a few minutes at 108°.

The most favourable point in the temperature of the atmosphere is also 32°. If the season have maintained this point for some days antecedently to the frog's being plunged under water, itself of 32°, the animal will live from 24 to 60 hours. De l'Influence des Agens Physiques sur la Vie; also, Memoires sur l'Asphyxie, &c. 1817. Paris, 8vo. 1824.

Edinburgh Medical Essays for 1720, Dr. Eccles makes mention of a beautiful young lady, "about sixteen years of age," who, in consequence of the sudden death of an indulgent father, was thrown into a state of tetanus, or rigidity of all the muscles of the body, and especially those of deglutition, so violent as to render her incapable of swallowing for two long and distinct periods of time; in the first instance for thirty-four, and in the second, which occurred shortly afterwards, for fifty-four days; during "all which time, her first and second fastings, she declared," says Dr. Eccles, "she had no sense of hunger or thirst; and when they were over, she had not lost much of her flesh."

In our own day we have had nearly as striking instance of this extraordinary fact, in the case of Anne Moore, of Tutbury in Staffordshire, who, in consequence of a great and increasing difficulty in swallowing, at first limited herself to a very small daily portion of bread alone, and on March 17, 1807, relinquished even this, allowing herself only occasionally a little tea or water, and in the ensuing September pretended to abstain altogether from liquids as well as solids. From the account of Mr. Granger *, a medical practitioner of reputation, who saw her about two years afterwards, she appears to have suffered very considerably, either from her abstinence,

* Edinburgh Med. and Surg. Journal. No. xix. July 1809, p. 319.

or from that general morbid habit which induced her to use abstinence. He says, indeed, that her mental faculties were entire, her voice moderately strong, and that she could join in conversation without undergoing any apparent fatigue: but he says, also, that her pulse was feeble and slow; that she was altogether confined to her bed; that her limbs were extremely emaciated; that convulsions attacked her on so slight an excitement as surprise, and that she had then very lately lost the use of her lower limbs.

It afterwards appeared, that in this account of herself she was guilty of some degree of imposition, in order to attract visitors, and obtain pecuniary grants. Dr. Henderson, another medical practitioner, of deserved repute in the neighbourhood, had suspected this, and published his suspicions*: and an intelligent committee was at length arranged, and assented to by the woman herself, for the purpose of watching her by day and by night. Cut off hereby altogether from fluids, which she had of late pretended to relinquish, as well as from solids, she was hardly able to reach the tenth day, and still less to confess, as she then did, that she had occasionally been supplied by her daughter with water and tea. "On the whole," the committee conclude, in their account of her, "though this woman is a

* An examination of the imposture of Ann Moore, called the fasting woman of Tutbury, &c. By Alexander Henderson, M.D. 8vo. 1813.

base impostor with respect to her pretence of *total* abstinence from all food whatever, liquid or solid, yet she can perhaps endure the privation of solid food longer than any other person. It is thought by those best acquainted with her, that she existed on a mere trifle, and that from hence came the temptation to say that she did not take any thing. If, therefore, any of her friends could have conveyed a bottle of water to her, unseen by the watch, and she could occasionally have drunk out of it, little doubt is entertained that she would have gone through the month's trial with credit. The daughter says that her mother's principal food is tea, and there is reason to believe this to be true.*" But this opinion leaves the case almost as extraordinary as before the detection of the fraud; for if true, and it is greatly borne out by the fact to which it appeals, this woman was capable of subsisting on what is ordinarily regarded as no nutriment whatever, and required nothing more for her support than an occasional draught of pure water.

Hildanus, Haller, and other physiologists, have collected various instances of a similar kind: many of them of a much longer duration of abstinence; some of them, indeed, extending to

* A full exposure of Ann Moore, the pretended fasting woman of Tutbury, 8vo. 1813.

The newspapers have informed us that this poor woman died at Macclesfield about the beginning of October 1825, at the advanced age of 76.

not less than sixteen years; but in general too loosely written and attested to be entitled to full reliance. Yet the Philosophical Transactions in their different volumes contain numerous cases of the same kind, apparently drawn up with the most scrupulous caution, and supported by the best kind of concurrent evidence. In one of the earlier volumes * we meet with an account of four men who were compelled to subsist upon water alone for twenty-four days, in consequence of their having been buried in a deep excavation by the fall of a superincumbent stratum of earth under which they were working, and it being this length of time before they were extricated. The water which they drank of was from a spring at hand; and they drank of it freely, but tasted nothing else.

A still more extraordinary account is recorded in the same journal for the year 1742, and consists of the history of a young man, who at the age of sixteen or seventeen, from having drunk very freely of cold water when in a violent perspiration, was thrown into an inflammatory fever, from which he escaped with difficulty, and with such a dislike to foods of all kinds, that for *eighteen years*, at the time this account was drawn up, he had never tasted any thing but water. The fact was well known throughout the neighbourhood; but an imposition having been suspected by several persons who saw him,

* Phil. Trans. 1684.

he had been shut up at times in close confinement for twenty days at a trial, with the most scrupulous care that he should communicate with nothing but water. He uniformly enjoyed good health, and appears to have had ejections, but seldom.

A multitude of hypotheses have been offered to account for these wonderful anomalies, but none of them do it satisfactorily; and I should be unworthy of the confidence you repose in me, if I did not ingenuously confess my utter ignorance upon the subject. Water in most cases appears to have been absolutely necessary, yet not in all; for Hildanus, who, though somewhat imaginative, appears to have been an honest and an able man in the main, assures us, that Eva Flegen, who had fasted for sixteen years when he saw her in 1612, had abstained entirely from liquids as well as solids: and in the case of impacted toads, especially those found in blocks of closely crystallized marble, the moisture they receive must often be very insignificant.

Perhaps one of the most singular cases, and at the same time one of the best authenticated on record, is that of Janet M'Leod, published in the Philosophical Transactions by Dr. Mackenzie.* She was at this time thirty-three years of age, unmarried, and from the age of fifteen had had various paroxysms of epilepsy, which

* Vol. lxvii. year 1777.

had considerably shaken her frame, rendered the elevator muscles of the eye-lids paralytic, so that she could only see by lifting the lids up, and produced so rigid a locked jaw that her mouth could rarely be forced open by any contrivance. She had lost very nearly her power of speech and deglutition, and, with this, all desire either to eat or drink. Her lower limbs were retracted towards her body; she was entirely confined to her bed, slept much, and had seldom any other egestions than periodical discharges of blood, apparently from the lungs, which was chiefly thrown out by the nostrils. During a very few intervals of relaxation she was prevailed upon with great difficulty to put a few crumbs of bread, comminuted in the hand, into her mouth, together with a little water sucked from her own hand, and in one or two instances a little gruel; but even at these attempts almost the whole was rejected. On two occasions also, after a total abstinence of many months, she made signs of wishing to drink some water, which was immediately procured for her. On the first occasion, the whole seemed to be returned from her mouth; but she was greatly refreshed by having it rubbed upon her throat. On the second occasion, she drank off a pint at once, but could not be either prevailed upon or forced to drink any more, notwithstanding that her father had now fixed a wedge between her teeth, two of which were hereby broken out. With these exceptions, however, she seems to have

passed upwards of four years without either liquids or solids of any kind, or even an appearance of swallowing. She lay for the most part like a log of wood, with a pulse scarcely perceptible from feebleness, but distinct and regular: her countenance was clear and pretty fresh; her features neither disfigured nor sunk; her bosom round and prominent, and her limbs not emaciated. Dr. Mackenzie watched her with occasional visits, for eight or nine years, at the close of which period she seems to have been a little improved. His narrative is very precisely as well as minutely detailed, and previously to its being sent to the Royal Society was read over before the patient's parents, who were known to be persons of great honesty, as also before the elder of the parish, who appears to have been an excellent man; and, when sent, was accompanied by a certificate as to the general truth of the facts, signed by the minister of the parish, the sheriff-depute, and six other individuals of the neighbourhood, of high character, and most of them justices of the peace.

Yet even with the freest use of water, what can we make of such cases upon any chain of chemical facts at present discovered? what can we make of it, even in conjunction with the use of air? The weight and solid contents of the animal body is derived hiefly from that principle which modern chemists denominate carbone; yet neither water nor air, when in a state of purity, contains a particle of carbone. Again,

the substance of the animal frame is distinguished from that of the vegetable by its being saturated with nitrogene, of which plants possess comparatively but very little; yet though the basis of atmospherical air consists of nitrogene, water has no more of this principle than it has of carbone; nor is it hitherto by any means established, that even the nitrogene of the animal system is in any instance derived from the air, or introduced by the process of respiration: for the experiments upon this subject, so far as they go, are in a state of opposition, and keep the question on a balance—*factis contraria facta.*

Shall we then suppose with others, that the circle of perpetual mutation, which is imposed upon every other species of visible matter, is in these cases suspended, and that the different organs of the system are, so long as the anomaly continues, rendered incorruptible. But this is to suppose the intervention of a miracle, and without an adequate cause. Let us then rather confess our ignorance than attempt to be wise upon the basis of conceit. All that we do know is, that bodies of every kind are reducible to a few elementary principles, which appear to be unchangeable, and are certainly invisible; and that from different combinations and modifications of these proceeds every concrete and visible form: hence air itself, and water; hence mineral, vegetable, and animal substances. Air, therefore, and water, or either separately, may contain the rudimental materials of all the rest.

We behold metallic stones, and of large magnitude, fall from the air, and we suppose them to be formed there: we behold plants suspended in the atmosphere, and still, year after year, thriving, and blooming, and diffusing odours: we behold insects apparently sustained from the same source; and worms, fishes, and occasionally man himself, supported from the one or the other, or from both. These are facts, and as facts alone we must receive them, for we have at present no means of reasoning upon them. There are innumerable mysteries in matter as well as in mind; and we are not yet acquainted with the nature of those elementary principles from which every compound proceeds, and to which every thing is reducible. We are equally ignorant of their shapes, their weight, or their measure.

LECTURE XIII.

ON THE CIRCULATION OF THE BLOOD, RESPIRATION, AND ANIMALIZATION.

The progress of science is slow, and often imperceptible; and though in a few instances it has been quickened by an accidental discovery or an accidental idea, that has given a new turn, or a new elasticity to the chain of our reasoning, still have we been compelled in every instance to follow up the chain, link after link, and series after series, and have never leaped forward through an intermediate space without endangering our security, or being obliged to retrace our career by a painful and laborious re-investigation.

It required a period of three thousand six hundred years to render the doctrine of a vacuum probable, and of five thousand six hundred to establish it upon a solid foundation. For its probability we are indebted to Epicurus, for its certainty to Sir Isaac Newton. The present theory of the solar system was commenced by Pythagoras and his disciples five centuries before Christ, and only completed by Copernicus fifteen centuries after Christ. Archimedes was the first who invented the celebrated problem

for squaring the parabola, which was upwards of two hundred years before the Christian era; yet an exact problem for squaring the circle is a desideratum in the present day. The simple knowledge of the magnet was familiar to the Romans, Greeks, and some of the oriental nations while in their infancy; it has been employed by the mariner for nearly six centuries in Europe, and for a much longer period by the Chinese, in their own seas; yet at this moment we are acquainted with only a very few of its laws, and have never been able to appropriate it to any other purpose than that of the compass.

The circulation of the blood in the animal system is our subject of study for the present lecture, and it is a subject which has laboured under the same difficulties, and has required as long a period of time as almost any of the preceding sciences, for its complete illustration and establishment. Hippocrates guessed at it; Aristotle believed it; Servetus, who was burnt as a heretic in 1553, taught it; and Harvey, a century afterwards, demonstrated it.

I shall not here enter into the various steps by which this wonderful discovery was at length effected; the difficulty can be only fairly appreciated by those who are acquainted with the infinitely minute tubes into which the distributive arteries branch out, and from which the collective veins arise; but every one is interested in the important fact itself, for it has done more towards establishing the healing art

upon a rational basis, and subjecting the different diseases of mankind to a successful mode of practice, than any other discovery that has emblazoned the annals of medicine.

In our last lecture we traced the action of the digestive organs: we beheld the food first comminuted by means of jaws, teeth, or peculiar muscles or membranes; next converted into a pulpy mass, and afterwards into a milky liquid; and in this state drunk up by the mouths of innumerable minute vessels, that progressively unite into one common trunk, and convey it to the heart as the chief organ of the system, for the use and benefit of the whole.

But the new-formed fluid, even at the time it has reached the heart, has by no means undergone a sufficient elaboration to become genuine blood, or to support the living action of the different organs. It has yet to be operated upon by the air, and must for this purpose be sent to the lungs, and again returned to the heart, before it is fitted to be thrown into the general circulation.

This is the rule that takes place in all the more perfect animals, as mammals, birds, and most of the amphibials *; and hence these classes are

* Cuvier seems to ascribe a double heart to the class of amphibia, without any limitation. See Lawrence's additional note E. chap. xii. of his translation of Blumenbach's System of Comparative Anatomy. Blumenbach himself has remarked, that many of the frogs, lizards, and serpents have a simple heart, consisting of a single auricle and ventricle, like that of fishes. Sect. 162.

said to have a double circulation. And as the heart itself consists of four cavities, a pair belonging to each of the two circulations, and each pair is divided from the other by a strong membrane, they are also said to have not only a double circulation, but a double heart — a pulmonary and a corporeal heart.

The blood is first received into the heart on the pulmonary side, and is conveyed to the lungs by an artery which is hence called the pulmonary artery, that soon divides into two branches, one for each of the lungs; in which organs they still further divide into innumerable ramifications, and form a beautiful net-work of vessels upon the air-vesicles of which the substance of the lungs consists; and by this mean every particle of blood is exposed in its turn to the full influence of the vital gasses of the atmosphere, and becomes thoroughly assimilated to the nature of the animal system it is to support. The invisibly minute arteries now terminate in equally minute veins, which progressively unite till they centre in four common trunks, which carry back the blood, now thoroughly ventilated and of a florid hue, to the left side or corporeal department of the heart.

From this quarter the corporeal circulation commences: the stimulus of the blood itself excites the heart to that alternate contraction which constitutes pulsation, and which is continued through the whole course of the arteries; and by this very contraction the blood is impelled to the remotest part of the body, the

arterial vessels continuing to divide and to subdivide, and to branch out in every possible direction, till the eye can no longer follow them, even when aided by the best glasses.

The arterial blood having thus visited every portion of every organ, and supplied it with the food of life, is now returned, faint, exhausted, and of a purple hue, by the veins, as in the pulmonary circulation; it receives, a short space before it reaches the heart, its regular recruit of new matter from the digestive organs, and then empties itself into the right side or pulmonary department of the heart, whence it is again sent to the lungs, as before, for a new supply of vital power.

The circulation of the blood, therefore, depends upon two distinct sets of vessels, arteries and veins, the former of which carry it forward to every part of the system, and the latter of which return it to its central source. Both sets of vessels are generally considered as consisting of three distinct layers or tunics: an external, which in the arteries is peculiarly elastic; a middle, which is muscular in both, but whose existence is doubted by some physiologists; and an internal, which may be regarded as the common covering or cuticle. The projectile power exercised over the arteries is unquestionably the contraction to which the muscular tunic of the heart is excited by the stimulus of the blood itself; and which contraction would be permanent, but that the heart appears to

become exhausted in a considerable degree of its muscular irritability by the exertion that produces the contraction, and hence speedily returns to its prior state of relaxation, exhibiting that alternating succession of systole and diastole which constitutes pulsation.*

In the venal system, however, we meet with even fewer proofs of muscular fibre than in the arterial, and no such force of the heart as to produce pulsation on a pressure of the finger; and hence, to this moment, we are in a greater degree of ignorance as to the projectile power by which this system is actuated. The theories that have been chiefly advanced upon the subject are, first, that of a vis à tergo, or an impetus given to the blood by the arterial contraction, which is supposed by its supporters to be sufficient to operate through the whole length of the venal canals; secondly, that of capillary attraction, the nature of which we explained in a former lecture; and lastly, a theory of a much more complicated kind than either, and which supposes the projectile power to result jointly from the impetus communicated by the heart and arteries,

* Physiological experiments have sufficiently proved, of late, that the same alternation of contraction and dilatation does not take place in the arteries in a free or natural state; for where there is no resistance to the flow of the blood along their canals, there is no variation in their diameter; and that it is only the pressure of the finger or some other substance against the side of an artery that produces its pulse. Study of Med. ii. p. 16. Experimental Inquiry into the Nature, &c. of the Arterial Pulse, by C. H. Parry, M. D. 1816.

from the pressure of the surrounding organs, and especially from the elasticity of the lungs, and the play of the diaphragm, in conjunction with the natural irritability of the delicate membrane that lines the interior of the veins. It is unnecessary to enter into a consideration of any of these theories; for they all stand self-convicted of incompetency; and the last, which is the most operose of the whole, has been only invented to supply the acknowledged inefficacy of the other two.* Whatever this projectile power consists of, it appears to have some resemblance to that of the vegetable system; and, like many of the vessels in the latter, is assisted by the artifice of numerous valves inserted in different parts of the venal tubes.

The most important process which takes place in the circulation of the blood is that of its ventilation in the lungs. It is this process which constitutes the economy of RESPIRATION, and has

* It has lately been pretty clearly established, that by far the most active power in the return of the blood to the heart from the veins is the comparative vacuum which takes place in the ventricles of the heart, when exhausted of blood by the systole or alternating contraction of this organ; in consequence of which, the venous blood is, as it were, sucked up into the right ventricle from the venæ cavæ, or venous system at large. So that the heart, upon this beautiful principle of simplification, becomes alternately a forcing and a suction pump. By its contraction it forces the blood into the arterial system, and by its vacuum it sucks it up from the venous. See Stud. of Med, ii. p. 19, 2d edit. 1825.

till of late been involved in more than Cimmerian darkness.

We see the blood conveyed to the lungs of a deep purple hue, faint and exhausted by being drained in a considerable degree of its vital power, or immature and unassimilated to the nature of the system it is about to support, in consequence of its being received fresh from the lacteal trunk. We behold it returned from the lungs spirited with newness of life, perfect in its conformation, more readily disposed to coagulate, and the dead purple hue transformed into a bright scarlet. How has this wonderful change been accomplished? what has it parted with? what has it received? and by what means has so beneficial a barter been produced?

These are questions which have occupied the attention of physiologists in almost all ages; and though we have not yet attained to any thing like demonstration, or even universally acceded to any common theory, the experiments of modern times have established a variety of very important facts which may ultimately lead to such a theory, and clear away the difficulties by which we are still encumbered.

These facts I shall proceed to examine into in language as familiar as I can employ: I must nevertheless presume upon a general acquaintance with the elementary principles and nomenclature of modern chemistry, since a summary survey of zoonomy is not designed to enter into a detail of its mere alphabet or rudiments, but

to apply and harmonize detached facts that relate to it, and to condense the materials that have been collected by others into a narrow but regular compass.

The chief substance which has been ascertained to be introduced from the atmosphere into the air-vesicles of the lungs during the act of respiration, and from these into the blood, is oxygene, of which the atmosphere, when pure, consists of about twenty-eight parts in a hundred, the remaining seventy-two being nitrogene.

That this gasseous fluid enters into the lungs is rendered highly probable from a multiplicity of experiments, which concur in proving that a larger portion of oxygene is received by every act of inspiration than is returned by every correspondent act of expiration; and that it passes from the air-vesicles of the lungs into the blood we have also reason to believe from the change of colour which immediately takes place in the latter, and from other experiments made out of the body, as well as in the body, which abundantly ascertain that oxygene has a power of producing this change, and of converting the deep purple of the blood into a bright scarlet.

It is also supposed very generally, that a considerable portion of caloric or the matter of heat, in its elementary form, is communicated to the blood at the same time and in conjunction with the oxygene; but as this substance has hitherto proved imponderable to every scheme that has been devised to ascertain its weight, this con-

tities at present a point avowedly undetermined. That an increase of sensible heat at all times accompanies an increase of respiration, is admitted by every one; but since caloric may be obtained by other means, if obtainable at all, and since a denial of its existence as a distinct substance has of late years been as strenuously urged as it was in former times by the Peripatetic school, and upon experiments inaccessible to those philosophers, we are at present in a state of darkness upon this subject, from which I am much afraid we are not likely to be extricated very soon.

"I have already observed that nitrogene, or azote as it is also called, is the other gasseous fluid that constitutes the respirable air of the atmosphere. And from a variety of well-conducted experiments by Mr., now Sir Humphrey, Davy, it appears also that a certain quantity of this gass is imbibed by the lungs in the same manner they imbibe oxygene, and that like oxygene it is also communicated from the lungs to the blood while circulating through its substance; for in the experiments adverted to he found that, as in the case of the oxygene, a smaller quantity was always returned by every successive act of expiration than had been inhaled by every previous act of inspiration. *

The only gass that seems to have been thrown out from the lungs in the course of these ex-

* Priestley had before shown that nitrogene is absorbed. See Phil. Trans. 1790, p. 106.

periments is carbonic acid; a very minute proportion of which appears also to be almost always contained in the atmospheric air, though altogether a foreign material, probably eliminated from the decomposition of animal and vegetable bodies that is perpetually taking place, and certainly unnecessary to healthful respiration.

The general result of these experiments was as follows: the natural inspirations were about twenty-six or twenty-seven in a minute; thirteen cubic inches of air were in every instance taken in, and about twelve and three quarters thrown out by the expiration that succeeded.

The atmospheric or inspired air contained in the thirteen cubic inches,—nine and a half of nitrogene, three and four-tenths of oxygene, and one-tenth of an inch of carbonic acid. The twelve inches and three quarters of returned air contained nine and three-tenths of nitrogene, two and two-tenths of oxygene, and one and two tenths of carbonic acid.

This inhalation, however, varies in persons of different sized chests from 26 to 32 cubic inches, at a temperature of 55°; but these by the heat of the lungs, and saturated with moisture, become forty or forty-one cubic inches.

Taking, therefore, 40 cubic inches as the quantity of air equally inhaled and exhaled about 20 times in a minute, it will follow that a full grown person respires 48,000 cubic inches in an

hour, or 1,152,000 cubic inches in the course of a day; a quantity equal to about 79 hogsheads.

A similar train of experiments has more lately been pursued by Messrs. Allen and Pepys, and will be found fully detailed in the Transactions of the Royal Society for 1808. They confirm the preceding proportions, excepting in the retention of nitrogene; this substance having been found by Messrs. Allen and Pepys to have been returned, in every respiration, in the precise proportion in which it was received. It is highly probable, however, that the diet of these two sets of ingenious experimenters had not previously consisted of the same proportion of animal and vegetable materials; and that the blood in the former instance was less charged with nitrogene than in the latter; which would at once account for the difference.

Upon Sir Humphry Davy's experiments, however, the quantity of nitrogene received by the lungs is very inconsiderable, not amounting to more than two-tenths of a cubic inch in an inspiration. And omitting the consideration of this gass, as also that of caloric, on account of the unsettled state of the question, respiration, from this view of the subject, consists merely in the act of receiving oxygene, and throwing out carbonic acid gass; the lungs imbibing and communicating to the system not less than 32.4 cubic inches of the former, and parting with not less than 26.5 of the latter, every minute. So that,

taking the gravity of carbonic acid gass, as calculated by Lavoisier, eleven ounces of solid carbon or charcoal are emitted from the lungs every twenty-four hours.*

The whole of the theory and some of the supposed facts here advanced, however, have of late been very considerably disputed by Mr. Ellis, in his Inquiry into the Changes induced on Atmospheric Air by the Germination of Seeds. He concurs with Messrs. Allen and Pepys, in ascertaining that precisely the same quantity of nitrogene is expired as is inspired; but he objects to their conclusion, that the whole of any constituent element of respired air introduced into the air-vesicles, and not returned by the alternate expiration, is *necessarily* conveyed into the blood-vessels, believing that much of this may remain unascertained, in consequence of an increased, but not sensibly increased, expansion of the chest. He admits that carbonic vapour is thrown forth in the quantity usually alleged with every act of expiration; but he offers evidence to prove that it is the carbone only that is discharged from the animal system, in connexion with the exhaling vapour; contending that the carbone thus existing is separated from the vapour by its union with *the whole of the oxygene* introduced by the previous act of inspiration, by which alone it is converted into

* Phil. Trans. 1808, part ii. 249.

carbonic acid gass: for he found the same decomposition of atmospheric air produced by introducing a small bladder, moistened, and filled with any substance, or perfectly empty, and introduced into an inverted glass containing a certain proportion of atmospheric air, standing upon quicksilver. He denies, therefore, that the air-vessels are in any degree porous to gasses of any kind, excepting caloric; and, consequently, denies that the blood is converted from a deep modena hue into a bright scarlet by its union with oxygene; believing, or seeming to believe, that this result is entirely produced by the action of the caloric separated in the air-vesicles upon the union of the carbone of the vapour exhaled from their surfaces, with the oxygene introduced by inspiration. So that, according to this theory, respiration is nothing more than an introduction of caloric into the system, and the conversion of a portion of oxygene (the whole received by the act of inspiration) into an equal bulk of carbonic acid by the carbone exhaled from the living organized body. Air, therefore, examined after respiration, is found to differ from the same air before it is breathed, in having lost a portion of oxygene, gained an equal volume of carbonic acid, and in being loaded with pure watery vapour, the vapour thrown off from the lungs; and he has offered an additional proof that the oxygene of the carbonic acid is that introduced in the act of inspiration, by showing, as in the

case of breathing hydrogene gass, that no carbonic acid is returned, and apparently none produced.

In opposition to the hypothesis of Dr. Priestley, he seems to show, and plausibly to establish, that all terrestrial plants, whether growing in absolute darkness, in the shade, or exposed to the direct rays of the sun, are constantly removing a quantity of oxygene from the atmosphere, and substituting an exactly equal volume of carbonic acid: that they produce this change by emitting from their leaves, flowers, fruits, stems, and roots, and by a process like animal exhalation, carbonaceous matter, which combines with the oxygene of the surrounding air; and that such a function is essentially necessary to their vital existence. In doing this, however, the carbonaceous matter is given forth more freely from the green parts than from any other, especially when exposed to the direct rays of the sun, by means of its affinity for the calorific rays; in consequence of which the oxygene of the carbone is set at liberty, and escapes from the cellular texture of the green parts through the external pores; an action, however, which is not necessary to life, for a plant does not die when this has ceased, while it is equally found to occur in a dead as in a living plant. It was probably this occasional escape of oxygene that induced Priestley to regard it as an invariable and constant process, affording a compensation for the animal carbone thrown into the air, and thus taking from and giving to

the animal world what seemed to be mutually demanded.

Mr. Ellis also affirms that all the various colours of vegetables depend on the varied proportion of alkaline and acid matter mixed with the juices of the coloured parts of plants: that green and yellow, for example, are always produced by an excess of alkali in the colourable juices of the leaf or flower; and all the shades of red, by a predominance of acid; while a neutral mixture produces a white. And hence there is most green in the summer season, when the oxygene is parted with most freely, as drawn away by the rays of light; while in autumn, when there is less separation, the other colours of yellow and red are most frequent.

Mr. Ellis has also quoted a variety of experiments on different kinds of fishes, muscles, marine testacea, snails, leeches, zoophytes, and tadpoles, in which it was found that the water wherein these animals had been placed had lost a part of its oxygene, and received an addition of carbonic acid, while its nitrogene had remained unaffected.*

This hypothesis, however, requires confirmation, and is at present open to many objections. If caloric can permeate animal membranes, as Mr. Ellis admits it to do, and unite by chemical affinity with the blood in the blood-vessels, so also

* Inquiry into the Changes induced on Atmospheric Air by the Germination of Seeds, &c. 8vo. 1807. As also, Further Inquiries into the Changes, &c. 8vo. 1811.

may oxygene in certain cases of combination. Mr. Porrett has shown that the Voltaic fluid, when operating upon water, is capable of carrying even water itself through a piece of bladder, and of raising it into a heap against the force of gravitation; and hence other affinities may not only introduce the oxygene of the respired air, or a part of it, into the blood of the blood-vessels in the lungs, through the tissue of the air-cells, but at the same time carry off the superabundant carbone in the form of carbonic acid, instead of its being thrown out in that of carbonic vapour. Nor have we any proof that carbone will dissolve in water, and produce such vapour; and hence such an idea is gratuitous.*

Of the general operation, however, there is no doubt, whatever be the manner in which it is performed: and by such operation the new blood becomes assimilated to the nature of the system it has to nourish; and the old or exhausted blood both relieved from a material that may be said to suffocate it, and reinspirited for fresh action. In this state of perfection, produced from the matter of food introduced into the stomach, and elaborated by the gasses of the atmosphere, received chiefly by the act of respiration, but perhaps partly also by the absorbing pores of the skin, the blood on its analysis is found to consist of the following nine parts, independently of

* Stud. of Med. edit. ii. vol. i. p. 474. Thomson's Annals of Philos. No. xliii. pp. 75, 76.

its aerial materials:—first, a peculiar aroma, or odour, of which every one must be sensible who has been present at a slaughter-house on cutting up the fresh bodies of oxen; secondly, fibrine, or fibrous matter; thirdly, uncoagulable matter, but no gelatine, which is a subsequent secretion; fourthly, albumen; fifthly, red colouring matter; sixthly, iron; seventhly, sulphur; eighthly, soda; and, lastly, water. The proportion of these parts vary almost infinitely, according to the age, temperament, and manner of living; each of these having a character that essentially belongs to it, with particular shades that are often difficult to be laid hold of.

Of these component parts, the most extraordinary are the red colouring matter, the iron, and the sulphur; nor are we by any means acquainted with the mode by which they obtain an existence in the blood. I have already had occasion to observe, that albumen and fibrine are substances formed by the action of the living principle out of the common materials of the food, and that it is probable the lime found in the bones and other parts is produced in the same manner. Whether the iron and sulphur that are traced in the blood have a similar origin, or exist in the different articles of our diet, and are merely separated from the other materials with which they are combined, is a physical problem that yet remains to be solved. It should be observed, however, that the sulphur does not exist in a free state even in the blood itself, but is only a com-

ponent part of its albumen. Considering the universality of these substances in the blood, and the uniformity of their proportion in similar ages, temperaments, and habits, whatever be the soil on which we reside; that those who live in a country in which these minerals are scarcely to be traced have not less, while those who live in a country that overflows with them have not more; it is perhaps most rational to conclude, that they are generated in the laboratory of the animal system itself, by the all-controlling influence of the living principle.

The exact proportion of sulphur contained in the system has been less accurately ascertained than that of the iron, which last in an adult, the weight of whose blood may be estimated at 28lbs. *, ought usually to amount to seventy scruples, or about three ounces: and hence the blood of about forty men contains iron enough to make a good plough-share, and might easily have its iron extracted from it, be reduced to a metallic state, and manufactured into such an instrument.

Iron is seldom found except in the red particles of the blood †; and it has hence been

* Blumenbach states the proportion in an adult and healthy man to be as 1 to 5 of the entire weight of the body. By experiments on the water-newt (lacerta *palustris*), he found the proportion in this animal to be only as $2\frac{1}{2}$ to 36.

† Mr. Brande denies that iron exists more in the red particles of the blood than in the other principles: according to his experiments, it exists but in a very inconsiderable quantity

supposed by the French chemists to be the colouring material itself. The process of respiration, according to the theory of Lavoisier and Fourcroy, is a direct process of combustion, in which the animal system finds the carbone, and the atmosphere the oxygene and caloric; and in consequence of the sensible heat which is set at liberty during the combustion, the iron of the blood is converted into a red oxyde, and hence necessarily becomes a pigment.

But it is impossible to ascribe the red colour to this principle: for, first, we are by no means certain that the air communicates any such substance as caloric to the blood; and, secondly, let the sensible heat of the blood arise from whatever quarter it may, it can never be sufficiently augmented by the most violent degree, either of local or general inflammation, to convert the iron of the blood into a red oxyde, which, indeed, is never produced without rapid combustion, flame, and intense heat. And hence, Sir Humphry Davy conjectures the carbone itself of the blood to be the real colouring material, and to be separated from the

in any of them; but he has traced it in the chyle, in the serum, and in the fibrine, or washed crassament. Phil. Trans. 1812, p. 112. Vauquelin has traced it as a constituent in egg-shells and oyster-shells. Thomson's Annals of Philos. No. 1. p. 66. But Berzelius has proved Brande to be mistaken, and that iron exists largely in the blood, and is the cause of the red colour. See his Anim. Chemistry.

oxygene, with which it is necessarily united to constitute carbonic acid gass, by the matter of light, which he supposes to be introduced into the system in the act of respiration, instead of the matter of caloric; in consequence of which it immediately becomes a pigment. But the difficulties which attend this theory are almost, if not altogether, as numerous as those which attend the theory of combustion, and it is unnecessary to pursue the subject any farther.

In the Philosophical Transactions, and in several of the best established foreign Memoirs, we meet with a few very curious instances of spontaneous inflammation, or active combustion, having occurred in the human body. The accident has usually been detected by the penetrating smell of burning and sooty films, which have diffused themselves to a considerable distance; and the sufferers have in every instance been discovered dead, with the body more or less completely burnt up, and containing in the burnt parts nothing more than an oily, sooty, extremely fetid and crumbly matter. In one or two instances there has appeared, when the light was totally excluded, a faint lambent flame bickering over the limbs; but the general combustion was so feeble that the chairs and other furniture of the room within the reach of the burning body have in no instance been found more than scorched, and in most instances altogether uninjured.

It is by no means easy to explain these extraordinary facts, but they have been too frequent, and are too well authenticated in different countries, to justify our disbelief. In every instance but one the subjects have been females, somewhat advanced in life, and apparently much addicted to spirituous liquors. I shall hence only observe, in few words, that the animal body in itself consists of a variety of combustible materials; and that the process of respiration (though not completely established to be such) has a very near alliance to that of combustion itself: that the usual heat of the blood, taking that of man as our standard, is 98° of Fahrenheit, and under an inflammatory temperament may be 103° or 104°; and hence, though by no means sufficiently exalted for open or manifest combustion, may be more than sufficiently so for a slow or smothered combustion; since the combustion of a dung-hill seldom exceeds 81°, and is not often found higher in fermenting haystacks, when they first burst forth into flame. The use of ardent spirits may possibly, in the cases before us, have predisposed the system to so extraordinary an accident; though we all know that this is not a common result of such a habit, mischievous as it is in other respects. The lambent flame emitted from the body is probably phosphorescent, and hence little likely to set fire to the surrounding furniture. It is not certain whether this flame originates spon-

taneously, or is only spontaneously continued, after having been produced by a lighted substance coming too nearly in contact with a body thus surcharged with inflammable materials.

Such, then, are the circulatory and respiratory systems in the most perfect animals; as mammals, birds, and amphibials. It should be observed, however, that in birds the hollow bones themselves, and a variety of air-cells that are connected with them, constitute, as we have already had occasion to notice *, a part of the general respiratory organ, and endow them with that levity of form which so peculiarly characterises them, and which is so skilfully adapted to their intention. It should be remarked, also, that in most amphibious animals, and especially in the turtle, whose interior structure is the most perfect of the entire class, the two ventricles, or larger cavities of the heart, communicate something after the manner in which they do in the human fetus. The lungs of this class are for the most part unusually large; and they have a power of extracting oxygene from water as well as from air; whence their capability of existing in both elements. The oxygene, however, obtained from the water is not by a decomposition of the water into its elementary parts, but only by a separation of such air as is loosely combined with it; for if water be deprived of air or oxygene

* Vol. I. Ser. I. Lect. XI. p. 282.

the animal soon expires. We have already observed that some amphibials appear to possess only a single heart, and even that of a very simple structure.

In fishes the heart is single, or consists only of two compartments instead of four, and hence the circulation is single also. The gills in this class answer the intention of lungs, and the blood is sent to them for this purpose from the heart, in order to be deprived of its excess of carbone, and supplied with its deficiency of oxygene. It is not returned to the heart, as in the case of the superior animals, but is immediately distributed over the body by an aorta or large artery issuing from the organ of the gills. The oxygene in these animals is separated from the water instead of from the air; and for this purpose the water usually passes through the mouth before it reaches the gills: yet in the ray-tribe there is a conducting aperture on each side of the head, through which the water travels instead of through the mouth. In the lamprey it is received by seven apertures opening on each side of the head into bags, which perform the office of gills, and passes out by the same orifices, and not as has been supposed, by a different opening said to constitute its nostril.

In the common leech there are sixteen of these orifices on each side of the belly, which answer the same purpose. In the sea-mouse (aphrodita *aculeata*) " the water passes through

the lateral openings between the feet into the cavity under the muscles of the back." *

The siren possesses a singular construction, and exhibits both gills and lungs †; thus uniting the class of fishes with that of amphibials. Linnéus did not know how to arrange this curious animal, and shortly before his death formed a new order of amphibials, which he called MEANTES, for the purpose of receiving it. It ranks usually in the class of fishes.

The only air-vessels of the winged insects have a resemblance to the apertures of the lamprey, and are called stigmata. In most instances these are placed on each side of the body; and each is regarded as a distinct trachea, conducting the air, as M. Cuvier elegantly expresses it, in search of the blood, as the blood has no means of travelling in search of the air. ‡ They are of various shapes and number, and are sometimes round, sometimes oval, but more generally elongated like a button-hole. In the grasshopper they are twenty-four, disposed in four distinct rows.

The membranous tube that runs along the back of insects is called by Cuvier the dorsal vessel. It discovers an alternate dilation and contraction; and is supposed by many naturalists

* Sir E. Home, Phil. Trans. 1815, p. 260.

† Home's Life of Hunter, prefixed to Hunter's Treatise on the Blood, Inflammation, &c. p. xli.

‡ En un mot, le sang ne pouvant aller chercher l'air, c'est l'air qui va chercher le sang. Leçons d'Anat. Comp. i. 23. Sect. 2. Art. 5.

to be a heart, or to answer the purpose of a heart. Cuvier regards it as a mere vestige of a heart without contractions from its own exertion, and without ramifications of any kind: the contractions being chiefly produced by the action of the muscles running along the back and sides, as also by the nerves and tracheæ, or stigmata. Scorpions and spiders have a proper heart; and as the term *insects* is now confined by M. Cuvier and M. Marcel de Serres to those that have only this dorsal vessel, or imperfect heart, the two former genera are struck out of the list of insects as given by Linnéus. *

This organ differs very considerably in its structure and degree of simplicity in molluscous animals. The heart of the teredo has two auricles and two ventricles; that of the oyster one auricle and one ventricle. In the muscle the heart is not, strictly speaking, divided into an auricle and ventricle, but rather consists of an oval bag, through the middle of which the lower portion of the intestine passes. Two veins from the gills open into the heart, one on each side, which may be considered as the auricles.

In several of the crustaceous insects of Linnéus, as, for example, the monoculus and craw-fish, the stigmata converge into a cluster, so as to form gills; which in some species are found seated in the claws, and in other species under

* See M. Marcel de Serres' statement, Tilloch's Journal, vol. xliv. p. 148.; and especially Thomson's Annals of Phil. No. XXIII. p. 347, 348, 350, 354.

the tail. These have for the most part a small single heart, and consequently a single circulation, the course of which, however, is directly the reverse of that pursued in fishes; for the heart in the present instance propels the blood through the body, and the gills receive it, and propel it to the heart. This is also the case in the snail, slug, and many other soft-bodied worms, which possess a gill in the neck consisting of a single aperture, which it can open and shut at pleasure. Yet, with a singular kind of apparent sportiveness, the cuttle-fish is possest of three distinct hearts, which is one more than is allotted to mankind, in whom this organ is only double.

In zoophytes we are in great ignorance both as to their sanguineous and respiratory functions. That they stand in need of oxygene, and even of nitrogene, has been sufficiently determined by Sir H. Davy; as it has also that they absorb their oxygene and nitrogene, as fishes do, from the water which holds these gasses in solution. Their nutrition appears to be effected by an immediate derivation of the nutritive fluid from their interior cavity into the gelatinous substance of their body. *

Hence, then, the respiratory organs of the animal kingdom may be divided into three classes; lungs, gills, and holes or stigmata: each of the three classes exhibits a great variety in its form, but the office in which they are employed is the same. Animals of every kind

* Blumenbach, § 167.

must be supplied with air, or rather with oxygene, however they may differ in other respects in tenacity of life; for a vacuum, or a medium deprived of oxygene, kills them equally. Snails and slugs corked up in small bottles have been found to live till they had exhausted the air of every particle of oxygene, and to die immediately afterwards: and frogs and land-turtles, which are well known to survive the loss of the spinal marrow for months, and that of the head or heart for several days, die almost instantly on exposure to a vacuum.*

Connected with this general subject, there is still an important question to be resolved, and which has greatly occupied the attention of physiologists for the last fifty years.

Mediately or immediately, almost all animal nutriment, and consequently almost all animal organization, is derived from a vegetable source. The blade of grass becomes a muscular fibre, and the root of a yam or a potatoe a human brain. What, then, is that wonderful process which assimilates substances in themselves so unlike? that converts the vegetable into an animal form, and endows it with animal powers?

Now, to be able to reply succinctly to this question, it is necessary first of all to inquire into the chief feature in which animal and vegetable substances agree, and the chief feature in which they differ.

* See Encyclop. Brit. art. Physiol. p. 679.

Animals and vegetables, then, agree in their equal necessity of extracting a certain sweet and saccharine fluid, as the basis of their support, from whatever substances may for this purpose be applied to their respective organs of digestion. Animal chyle and vegetable sap make a very close approach to each other in their constituent principles, as well as in their external appearance. In this respect plants and animals agree. They disagree, inasmuch as animal substances possess a very large proportion of azote, with a small comparative proportion of carbone; while vegetable substances, on the contrary, possess a very large proportion of carbone, with a small comparative proportion of azote. And it is hence obvious, that vegetable matter can only be assimilated to animal by parting with its excess of carbone, and filling up its deficiency of azote.

Vegetable substances, then, part first of all with a considerable portion of their excess of carbone in the stomach and intestinal canal, during the process of digestion; a certain quantity of the carbone detaching a certain quantity of the oxygene existing in these organs, as an elementary part of the air or water they contain, in consequence of its closer affinity to oxygene, and producing carbonic acid gass; a fact which has been clearly ascertained by a variety of experiments by M. Jurine of Geneva. A surplus of carbone, however, still enters the animal system through the medium of the lacteals, and

continues to circulate with the chyle, or the blood, till it reaches the lungs. Here again a certain portion of carbone is perpetually parted with upon every exspiration, in the form of carbonic vapour, according to Mr. Ellis,* but, according to Sir H. Davy and others, in that of carbonic gass, in consequence of its union with a part of the oxygene introduced into the lungs with every returning inspiration *; while the excess that yet remains is carried off by the skin, in consequence of its contact with atmospheric air: a fact put beyond all doubt by the experiments and observations of M. Jurine. although, on a superficial view, opposed by a few experiments of Mr. Ingenhouz †, and obvious to every one, from the well-known circumstance that the purest linen, upon the purest skin, in the purest atmosphere, soon becomes discoloured.

In this way, then, and by this triple co-operation of the stomach, the lungs, and the skin, vegetable matter, in its conversion into animal, parts with the whole of its excess of carbone.

Its deficiency of azote becomes supplied in a two-fold method: first, at the lungs; also, by the process of respiration, as should appear from

* See Sir H. Davy's Researches Chemical and Philosophical, &c., and Mémoire sur la Chaleur, par M. M. Lavoisier et De la Place. Mem. de l Acad. De la Combustion, &c.

† Essaie de Théorie sur l'Animalization et l'Assimilation des Alimens, &c., Annales de Chimie, tom. ii.

the concurrent experiments of Dr. Priestley and Sir H. Davy *, which agree in showing that a larger portion of azote is inhaled upon every inspiration, than is returned by every succeeding expiration; in consequence of which the portion retained in the lungs seems to enter into the system, in the same manner as the retained oxygene, and perhaps in conjunction with it; while, in union with this economy of the lungs, the skin also absorbs a considerable quantity of azote, and thus completes the supply that is necessary for the animalization of vegetable food †: evincing hereby a double consent of action in these two organs, and giving us some insight into the mode by which insects and worms, which are totally destitute of lungs, are capable of employing the skin as a substitute for lungs, by breathing through the spiracles existing in the skin for this purpose, or merely through the common pores of the skin, without any such additional mechanism. It is by this mode, also, that respiration takes place through the whole vegetable world, offering us another

* See Davy's Researches Chemical and Philosophical, &c. and Priestley's Experiments and Observations on different Kinds of Air, vol. iii.

† M. Jurine is chiefly entitled to the honour of this discovery; his experiments coincide with several of Dr. Priestley's results, and have been since confirmed by other experiments of MM. Lavoisier and Fourcroy. See Premier Memoire sur la Transpiration des Animaux, par A. Seguin et Lavoisier, 1792; and compare with M. Hassenfratz's Mémoire sur la Combinaison de l'Oxygene, &c., Acad. des Scien. 1791.

instance of resemblance to many parts of the animal; in consequence of which, insects, worms, and the leaves of vegetables, equally perish by being smeared over with oil, or any other viscous fluid that obstructs their cutaneous orifices.

But to complete the great circle of universal action, and to preserve the important balance of nature in a state of equipoise, it is necessary, also, to inquire by what means animal matter is reconverted into vegetable, so as to afford to plants the same basis of nutriment which plants have previously afforded to animals?

Now, this is for the most part obtained by the process of PUTREFACTION, or a return of the constituent principles of animal matter to their original affinities, from which they have been inflected by the superior control of the vital principle, so long as it inhabited the animal frame, and coerced into other combinations and productions.* Putrefaction is, therefore, to be regarded as a very important link in the great chain of universal life and harmony.

The constituent principles of animal matter we have already enumerated: they are most of them compound substances, and fall back into

* It should hence appear, that putrefaction is the only positive criterion of death, or the total cessation of the principle of life. Galvanism has, indeed, been advanced as a decisive proof of the same by Behrends and Creve; but Humboldt has sufficiently shown its insecurity as an infallible test.

their respective primordia as the putrefactive process sets them at liberty. This process commences among the constituent gasses; and it is only necessary to notice the respective changes that take place in this quarter, as every other change is an induced result.

Of these gasses I have already observed, that azote or nitrogene is by far the largest in respect of quantity, and it appears also to be by far the most active. Hence, on the cessation of the vital principle, the azotic corpuscles very speedily make an advance towards those of oxygene, and generally in the softer and more fluid parts of the system; the control of the vital principle being here looser and less powerfully exerted. An union readily takes place between the two, and thus combined they fly off in the form of nitric acid; while at the same time another portion of azote combines with some portion of hydrogene, and escapes in the form of ammonia or volatile alkali. A spontaneous decomposition having thus commenced, all the other component parts of the lifeless machine are set at liberty, and fly off either separately, or in different combinations; during which series of actions, from the union of hydrogene with carbone, and especially if conjoined at the same time with some portion of phosphorus or sulphur, is thrown forth that offensive aura which is the peculiar characteristic of the putrefactive process, and which, according to the particular mode in which the different elementary sub-

stances combine, constitutes the fetor that escapes from putrid fishes, rotten eggs, or any other decomposing animal substances.

In this manner, then, by simple, binary, or ternary attractions and combinations, the whole of the substance constituting the animal system, when destitute of its vital principle, flies off progressively to convey new pabulum to the world of vegetation; and nothing is left behind but lime or the earth of bones, and soil or the earth of vegetables: the former furnishing plants with a perpetual stimulus by the eagerness with which it imbibes oxygene, and the latter offering them a food ready prepared for their digestive organs.

In order, however, that putrefaction should take place, it is necessary that certain accessaries to such a process should be present, without which putrefaction will never follow. Of these the chief are rest, air, moisture, and heat.

Without REST the putrefactive process in no instance takes place readily, and in some instances does not take place at all: for animal flesh, when exposed to the perpetual action of running water, is often found converted into one common mass of fat or spermaceti, as I shall presently have occasion to observe more minutely.

AIR must necessarily co-exist, for putrefaction can never be induced in a vacuum. Yet we must not only have air, but genuine atmo-

spheric air; or, in other words, the surrounding medium must be compounded of the gasses which constitute the air of the atmosphere, and in their just proportions. To prove this, it is sufficient to mention that dead animal substance has been exposed by M. Morveau *, and other chemists, for five or six years in confined vessels, to the action of simple nitrogene, hydrogene, carbone, and various other gasses, without any change that can be entitled to the appellation of putrefaction.

There must also be MOISTURE; for, as I have already observed, putrefaction commences in the softer and more fluid parts of the animal system. On this account it rarely occurs during a sere harmattan or drying wind of any kind, and never in a frost so severe as to destroy all moisture whatsoever; the power of frost exercising quite as effective a control over the elements of animal matter as the living principle itself.

For the same reason there must be HEAT; since in the total absence of heat frost must necessarily take place, together with an entire privation of moisture. On this last account, again, the heat made use of must only be to a certain extent, as about 65½° of Fahrenheit; for,

* See Mémoire sur la Nature des Fluides elastiques aëriformes, qui se dégagent de quelques Matieres animales, &c. par M. Lavoisier, Mem. de l'Acad. 1782; as also, M. Brugnatelli's paper in Crell's Chemical Annals for 1708, Ueber di Faulung thierischer theile in verschieden Luftarten.

if carried much higher, the rarefaction which takes place in the surrounding atmosphere will induce an ascent of all the fluids in the animal substance towards its surface; whence they will fly off in the form of vapour, before the putrefying process can have had time to commence, and leave nothing behind but dry indurated materials, incapable of putrefaction because destitute of all moisture. Our dinner tables too often supply us with instances of this fact, in dishes of roast or boiled meat too long exposed to the action of the fire, and hence reduced to juiceless and ragged fibres, totally devoid of nutriment, and capable of keeping for weeks or months, without betraying any putrefactive indication.

In like manner, when bodies are buried beneath the hot and arid sands of Egypt or Arabia, with a sultry sun shining, almost without ceasing, upon the sandy surface, the heat hereby produced is so considerable as to raise the whole of the fluids of the animal system to the cuticle, whence they are immediately and voraciously drunk up by the bibulous sands that surround it; or, piercing their interstices, are thrown off into the atmosphere in the form of insensible vapour. In consequence of which, when a body thus buried is dug up a few weeks after its interment, instead of being converted into its original elements, it is found changed into a natural mummy, altogether as hard and as

capable of preservation as any artificial mummy, prepared with the costliest septics employed on such occasions.

When dead animal organs are deposited in situations in which only a very small portion of atmospheric air is capable of having access to them, a change indeed takes place, but of a very different description from that of putrefaction, and which is of a most curious and extraordinary nature. For in such cases the animal organs, instead of being converted into their original elements, are transmuted into fat, wax, or spermaceti; or rather into a substance *sui generis*, and possessing a middle nature between that of the two former, whence the French chemists have given it the appellation of ADIPOCIRE; a term not strictly classical, but for which the chemists of our own country have not hitherto substituted any other.

This result is observed, not unfrequently, in bodies that are drowned, and rendered incapable of rising to the surface of the water; for in such a situation but very little air, and consequently very little oxygene, can reach them from the external atmosphere. And it is to these circumstances we ought, perhaps, to resolve the singular appearance in the body of Colonel Pollen, who was wrecked a few years ago in the Baltic sea, near Memel, and within sight of the coast; and whose corpse was six months afterwards thrown on shore, with the features of the face so little varied, that every one of his acquaint-

ance recognised him at the first glance. The body had probably been entangled in the submarine sands on first sinking, and been retained in this situation for months, cut off from that exposure to external air which is absolutely necessary in all cases of putrefaction properly so called. A similar conversion into wax-fat was observed also in 1786 and 1787, on opening the *fosses communes*, or common burial pits in the churchyard of the Innocents at Paris, for the purpose of laying the foundation of a new pile of buildings. For the bodies that on this occasion were dug up, instead of being dissolved into their elementary corpuscles, were found for the most part converted into this very substance of waxy fat or adipocire. The populace were alarmed at the phænomenon, and the chemists were applied to for an explanation. M. Fourcroy, among others, attended upon this occasion; and his solution, which will apply to all cases of a similar kind, referred the whole to the extreme difficulty with which external air had obtained any communication with the inhumed bodies, in consequence of the close adaptation of coffin to coffin, and the compactness with which every pit had been filled up. Difficult, however, as this communication must have been, he conceived that, from the natural elasticity of atmospheric air, some small portion of it had still entered, conveying, perhaps, just oxygene enough to excite the new action of decomposition. This having commenced, the constituent oxy-

gene of the dead animal organs would itself be progressively disengaged, and rapaciously laid hold of by all the other constituent principles, from their strong and general affinity to it. During this gradual evolution, there can be little doubt that the greater part of it would be seized by the predominant azote, a very considerable part by the carbone, and the rest by the hydrogene; and the result would be, upon the total but very slow escape of the constituent and disengaged oxygene, that the whole or nearly the whole of the azote, a considerable portion of the carbone, and a certain quantity of the hydrogene, would escape also—leaving behind the remainder of the carbone and the hydrogene, now incapable of escape from the want of oxygene to give wings to their flight, together with the residual earth of the animal machine.

But hydrogene and carbone, though in this case incapable of sublimation for want of oxygene, would still, from their mutual attraction and juxtaposition, enter into a new union and produce a new result, and this result must necessarily be fat; for fat is nothing else than a combination, in given proportions, of carbone and hydrogene. And hence, whatever the respective animal organs of the bodies deposited in these burial caverns may have antecedently consisted of, whether muscle, ligament, tendon, skin, or cellular substance, when thus deprived of their oxygene and azote, the whole must of necessity be converted into fat. Pure and

genuine fat it would have been, provided there had been nothing left behind but mere carbone and hydrogene, and in their respective proportions for the formation of fat; but as we can scarcely conceive such proportions could take place, or that every corpuscle of the azote could be carried off before the total escape of the oxygene, many parts of it must necessarily have assumed a flaky, soapy, or waxy appearance, from the union of the azote left behind, with some portion of the hydrogene, and the consequent production of ammonia or volatile alkali; since, by an intermixture of alkali with fat, every one knows that soap or a saponaceous substance is uniformly produced.

But, excepting in situations of this kind, in reality, in every situation in which dead animal matter, destitute of its living principle, is exposed to the usual auxiliaries of putrefaction, putrefaction will necessarily ensue, and the balance will be fairly maintained:—the common elements of vital organization will be set at liberty to commence a new career, and the animal world will restore to the vegetable the whole which it has antecedently derived from it.

In this manner is it, then, that nature, or rather that the God of nature, is for ever unfolding that simple, but beautiful round of action, that circle of eternal motion, in which every link maintains its relative importance, and the happiness of every part flows from the harmony of the whole. Can we, then, do better than conclude with the

correct and spirited apostrophe of one of our most celebrated poets: —

> Look round the world! behold the chain of love
> Combining all below and all above.
> See plastic nature working to this end;
> Atoms to atoms—clods to crystals tend.*
> See dying vegetables life sustain;
> See life dissolving, vegetate again.—
> All serv'd, all serving, nothing stands alone,
> The chain holds on, and where it ends unknown.

* This line is altered to answer the present purpose in better manner.

LECTURE XIV.

ON THE PROCESSES OF ASSIMILATION AND NUTRITION; AND THE CURIOUS EFFECTS TO WHICH THEY LEAD.

We have traced out in our preceding studies something of the means by which form, and magnitude, and motion, are produced in the inorganized world:—how the various substances that surround us combine and separate, vanish from us and re-appear, and, in the multifarious processes they undergo, give rise to new products by new and perpetually shifting involutions. We have further traced an outline of the means by which organized matter is capable of building up the curious structures of plants and animals; how the chief functions they possess are carried on, and by what means they respectively acquire maturity and perfection.

But it is not only necessary that the system should in this manner be matured and perfected by a fresh application of materials, but that the old materials which constitute every organ should be progressively removed from the system, in consequence of their being worn out by use, and their place supplied from definite stores. Let us, then, devote the present hour to an enquiry how this latter change occurs

in vascular and living matter, in the vegetable and animal system: by what means the dead or exhausted and worn-out elements of the different organs are carried off, and replaced by new reformative materials, and what are the principal phænomena that result from such a series of operations.

The blood, then, in animals, and the sap, which may be regarded as a species of blood, in plants, of both which we have already treated, are the vital currents from which every organ of the individual frame derives the nourishment it stands in need of, and into which it pours ultimately a considerable portion of its waste and eliminated fragments; for the provident frugality of nature suffers nothing to be lost, and, as far as possible, works up the old materials, time after time, into fresh food for the subsistence of the entire system.

To produce this double purpose two distinct sets of vessels are necessary: one for that of separating from the common mass of the blood, and re-combining into new associations, those particular parts of it which the formation of the fresh matter demands; and the other for that of carrying back the rejected materials into the general current. And hence these two sets of vessels bear the same relation to each other as the veins and arteries of the animal frame, accompany every part of the frame to its farthest extremities, and, indeed, constitute the general mass of the frame itself. From the

respective offices they perform, they are denominated SECERNENT and ABSORBENT systems: in their utmost ramifications they are too minute to be traced by the keenest eye, or the nicest experiment of the anatomist; but, where they are not quite so minute, they are sufficiently discoverable, and their course is sufficiently capable of being followed up, from the delicate apertures or mouths by which, in infinite numbers, they open on all animal surfaces, or hollows whatever, to their incipient sources.

The SECERNENTS, or that set of vessels whose office it is to separate particular parts from the blood for particular purposes, are evidently continuations of some of those very subtile ramifications of the arteries which, on account of their fineness, are called capillary; and the ABSORBENTS, or that set of vessels whose office it is to imbibe or drink up the waste and exhausted materials, are as evidently distinct and attenuate tubes, progressively uniting, and ultimately emptying themselves into the venous system, the common trunk in which they concentre, and in which also concentre the lacteals of the alimentary canal, named the thoracic duct, being a tough membranous channel situate upon the interior part of the spine, of about the diameter of a crow-quill in man, and running in a serpentine direction through the diaphragm or midriff to an angle formed by an union of the jugular and subclavian veins, into which it opens, and where of course it terminates, leaving the

waste and the new food, now intimately intermixed, to be still farther elaborated and refitted for use by those subsequent and specific operations of the heart and the lungs which we have already described. *

The simplest action, perhaps, that is evinced by the mouths of the secretory or secernent vessels, consists in separating and throwing forth a fine lymph from the surface of all membranes and organs whatever, for the purpose of lubricating them, as we grease the axle-tree of our carriage wheels; and thus preventing one membrane or organ from being injured by the friction of another. Of this every one who has been present on the cutting up of slaughtered oxen must have seen an abundant and striking instance, in the vapour that ascends from every part of the warm carcase, which vapour, when condensed by cold or any other cause, is found to be little

* This double action by a double set of vessels was little, if at all, known to the ancients, who referred the economy of both secretion and absorption to the powers of peculiar arteries and veins; and hence, the porosity of these vessels was a doctrine in common belief, till the time of Hewson, Hunter, and Cruickshank. M. Magendie and M. Flandrin, of Paris, have of late been very active in establishing a view of the subject in many respects not essentially different from that of the old school, and in teaching that the only general absorbents are the veins; that the lacteals absorb food, but nothing else; and that the lymphatics have no absorbent power whatever. Their experiments are plausible and striking, but by no means decisive enough to subvert the system explained above. The argument on both sides may be found in the author's Study of Medicine, Vol. v. p. 278. edit. 2d. 1825.

more than the serum or watery part of the blood. And one of the simplest actions evinced by the mouths of the absorbent vessels, consists in their drinking up, as with a sponge, this attenuate or lymphatic fluid, when it has answered its purpose, so as to make room for a fresh and perpetual effusion; whence these vessels are often called LYMPHATIC, as well as absorbent, in consequence of their being so frequently found loaded with this fine and colourless material.

And here, perhaps, the first remark that must occur to every one is the necessity there seems to exist, that these correspondent systems of vessels should maintain the nicest harmony or balance in their respective functions; since, if the one operate either with a less or a larger power than the other, disease must inevitably follow; the nature of the malady being determined by the nature of the cause that produces it.

We have all of us heard, and most of us have seen, instances of the disorder called dropsy; and many of us have surveyed it both in a local and a general form, as dropsy of the head, dropsy of the chest, dropsy of the abdomen, and dropsy of the cellular membrane or system at large. This disease may take place from two causes; as, for example, from a too great excitement of the secernent system, or a too little excitement of the absorbent. If, from a morbid irritability in the secernent vessels of any one of the cavities I have just adverted to, an undue

proportion of lubricating lymph be secreted and steam forth, the natural tone and action of the correspondent absorbent vessels will not be sufficient to carry off the surplus; and hence that surplus will accumulate, and dropsy ensue, although the absorbent vessels of the part affected be in a state of usual health and vigour: the disease depending altogether on the morbid and predominant excitement of the secernents.

But suppose the absorbent vessels of a particular cavity, in consequence of cold, exhaustion from great previous exercise, or any other cause, to be rendered torpid and inert, and consequently incapable of continuing their accustomed measure of action: in this case dropsy will also ensue, notwithstanding the corresponding secernent vessels are in a state of natural health, and no larger portion of lymph is secreted than a state of natural health demands; for the fluid will now accumulate, from the morbid torpitude of the absorbent system, and its inability to fulfil its function. It is hence, as every one must perceive, a point of the utmost consequence to determine the nature of the cause in dropsy, as, in truth, it is in every other disease, before we attempt a remedy; since an error upon this subject may be productive of the most serious, and indeed fatal consequences. For it is obvious that we may stimulate where we ought to diminish action, or we may diminish action where we ought to stimulate.

Occasionally, however, the action is equally increased in both sets of vessels; as, for example, in inflammation of the leg or arm; and in this case there is great heat and dryness, and at the same time considerable intumescence or swelling. For under this affection the mouths of the secernent vessels, being more distended than in a natural state, pour forth the coagulable lymph in a grosser and less attenuate form, and not unfrequently, perhaps, intermixed with some particles of red blood; while the mouths of the absorbents, though they as eagerly drink up the finer parts of what is thus rapidly strained off, are incapable of carrying away with equal ease those of a grosser texture; in consequence of which these last remain behind, and produce tumefaction by their accumulation.

At times, also, we meet with an equal degree of diminished instead of increased action in both these sets of vessels; as on exposure to cold and damp temperatures; in cases of spare and coarse diet; or of old age. And the result of this double decrease of energy is dryness, as in the former instance, but combined with leanness and corrugation of the organs that are thus affected. It is hence the bones of old people are more easily broken, and the skin is harsher and more wrinkled than in the middle of life; hence the shrivelled and squalid appearance of gipsies and beggars; and hence, in a considerable degree, the low and stinted stature of the Esquimaux, Laplanders, and Tongooses.

For all the usual purposes of health and organic nutrition, the common action and common degree of action evinced by these respondent systems of vessels are perfectly sufficient, though not more than sufficient. It may happen, however, that in consequence of severe violence from external injury or internal disease, a considerable portion of an organ, as a part of some of the muscles that belong to an arm or a leg, may be totally destroyed or killed, and consequently rendered incapable of performing its proper function. How is nature, or, which is the same thing, the remedial principle of life, to act in such circumstances? If the dead part remain, it is manifest that it must impede the living parts that surround it in the execution of their appropriate office; independently of which they want the space which the dead part occupies, and the aid which it formerly contributed. It is obvious that two processes are here necessary: the dead part must be carried off, and its post must be filled up by a substitute of new matter possessing the precise properties of the old. And here we meet with a clear and striking instance of that wonderful instinctive power which pervades every portion of the vital systems, both of the animal and vegetable world, and which is perpetually prompting them to a repair of whatever evils they may encounter, by the most skilful and definite methods.

In order to comply with this double demand of carrying off the dead matter, and of pro-

viding a substitute of new, each of the systems before us commences, in the living substance that immediately surrounds that which requires removal, a new mode and a new degree of action. A boundary line is first instinctively drawn between the dead and useless, and the living and active parts; and the latter retract and separate themselves from the former, as though the two had been skilfully divided by a knife. This process being completed, the mouths of the surrounding absorbent vessels set to work with new and increased power, and drink up and carry off whatever the material may be of which the dead part consists, whether fat, muscle, ligament, cartilage, or bone; the whole is equally imbibed and taken away, and a hollow is produced, where the dead part existed. At the same time the mouths of the corresponding secernent vessels commence a similar increase and newness of action, and instead of the usual lymph, pour forth into the hollow a soft, bland, creamy, and inodorous fluid which is denominated pus; that progressively fills up the cavity, presses gradually against the superincumbent skin, in the gentlest manner possible distends and attenuates it, and at length bursts it open, and exposes the whole of the interior to the action of the gasses of the atmosphere.

It was at one time conceived, and by writers of considerable eminence and judgment, and of as late a date as the time of Mr. Hewson, that the injured and dead parts were themselves dissolved

and converted into pus; but this opinion has been disproved in the most satisfactory manner by the minute and accurate experiments of Mr. John Hunter, Sir Everard Home, and Mr. Cruickshank; and the process has been completely established as I have now related it.

In what immediate way the gasses of the atmosphere operate so as to assist the secernent mouths of what is now the clean and exposed surface of a wound, in producing incarnation, or the formation of new matter of the very same kind and power as that which has been carried off, and enable them to fill up the cavity with such new matter, and perfect the cure, we do not exactly know. Various theories have been offered upon this very curious subject; but at present they are theories, and nothing more; and I shall not, therefore, detain you with a relation of them. Thus much, however, we do know, that the co-operation of the atmosphere with the action of the mouths of the secernent system engaged in the work of restoration is, in some way or other, peculiarly beneficial; and that, generally speaking, the wider the opening, and the freer the access of atmospheric air of a due temperature to the surface of the wound, or, which is the same thing, the freer it comes in contact with the mouths of the secernent vessels, the more rapidly and auspiciously the work of impletion and assimilation proceeds. Neither do we know, precisely, why pus, rather than any

other kind of fluid, should in the first instance be poured forth, for the purpose of filling up the hollow, and producing a rupture of the skin; but we know to a certainty that some such general process is in most cases absolutely necessary; we know that such a rupture must take place in the natural mode of cure; that the atmosphere must come into close contact with the mouths of the restorative secernents; that a milder or softer fluid could not possibly be secreted for such a purpose; and that the entire process exhibits proofs of most admirable skill and sagacity. It is at times possible for us to assist the process by the lancet, which accelerates the opening. Yet even in this case we do no more than assist it, and are only, as we ought ever to be in all similar cases, humble coadjutors and imitators of nature, and admirers of that all-perfect and ever-present wisdom which we are so often called upon to witness, but are never capable of rivalling.

A process closely similar to this is perpetually unfolding in vegetable life. And it was merely by taking advantage of this process that Mr. Forsythe was able to make old, but well-rooted, stumps of fruitt-rees throw forth, far more rapidly than he could saplings, a thrifty family of vigorous and well-bearing shoots: for the compost which he was so celebrated does nothing more than merely increase the secernent and absorbent action of the vegetable frame by its

stimulating property, and defend the wounded part to which it is applied from being injured by the inclemency of the weather.

From what has thus far been observed it appears obvious that all the different parts of the living body are assimilating organs, or, in other words, are capable of converting the common nutriment of the blood into their own respective natures, and for their own respective uses. And it has also appeared, that under particular circumstances every part is capable, moreover, of secreting a material different from that of its own nature, as, for example, the material of pus, whenever such a substance is necessary.

This view of the subject will lead us to understand with facility how it is possible for various organs of the system to maintain two distinct secretions at the same time: one of a matter similar to its own substance, and exclusively for its own use; and another of a matter distinct from its own substance, and in many instances subservient to the system in general.

Of this last kind are the stomach, the liver, the respiratory organ, and the brain: each of which secretes, independently of the matter for its own nourishment, a matter absolutely necessary to the health and perfection of the general machine; as the gastric juice, the curious and wonderful properties of which I described on a former occasion; the oxygenous principle of the inspired air, and, as some suppose, those of light

or caloric; the bile; and the nervous fluid, or material of sensation.

There are various other organs of a smaller kind, and simpler texture, which also perform the same double office, and secrete materials of a much more local use, or which are intended to be altogether thrown away from the system, as waste or noxious bodies. And to the one or the other of these classes belong the kidneys, the intestinal tube, the minute and very simple perspiratory follicles of the skin, the delicate organs that separate the saliva and mucus that serve to lubricate the mouth and nostrils, and those that elaborate the tears, the wax of the inner ear, and the fat.

The organs, of whatever size or texture, that perform this double function, are called secretory glands; and they are distinguished into different sets, either from their peculiar office or peculiar structure: as salivary, lachrymal, mucous, which are denominated from the former character, and apply to the smallest and simplest of them; conglobate, which are of a larger form, and of an intricate convolution, and belong exclusively to the absorbent system,—as the mysenteric and lumbar; and glomerate and conglomerate, which are composed of a congeries of sanguineous vessels, without any cavity, but with one or more mouths, or excretory ducts as they are called, which, in the latter, open into one common trunk,—as the mammary and pan-

creatic; both which kinds are denominated from the character of their structure.

It is by this peculiar organization in animals and plants that all those nice and infinitely varying exhalations or other fluids are thrown forth from different parts of them, by which such parts, or the whole individual, or the entire species of individuals, are respectively characterized. Our own senses are too dull to trace a discharge of any kind of essence or vapour from the surface of the human skin in its ordinary action; but the discoloration which soon takes place upon the purest linen, when worn in the purest atmosphere, sufficiently proves the existence of such an efflux; and there are various animals whose olfactory organs are much acuter than our own, as our domestic dogs, for example, that are able to discern a difference in the odour of the vapour which issues from the skin of every individual, and that in fact identify their respective masters, and distinguish them from other individuals by this character alone.

It is to this sense chiefly that quadrupeds, birds, fishes, and most insect tribes trust themselves, in their search after food; and hence the superior acuteness of this power in animals of such kinds is a strong proof of that unerring wisdom which regulates the world, and is equally conspicuous in every part of it. Under peculiar circumstances, however, the sense of smell appears to be far more lively among mankind than

when such circumstances do not exist. M. Virey, who has written a very learned treatise upon this subject, asserts, that it occurs among savages in a far higher degree of activity than among civilized nations, whose olfactory nerves are blunted by an habitual exposure to strong odours, or intricate combination of odours, and by the use of high-flavoured foods. And among persons in a keen morbid state of irritability it has been often found, even in civilized life, much sharper than among savages. The Journal des Sçavans, an. 1667, gives a curious history of a monk who was said to be able to ascertain, by the difference of odour alone, the sex and age of a person, whether he were married or single, and the manner of life to which he was accustomed. *

When the exhalation from the human skin is increased by muscular exercise, or any other exertion, it is rendered visible; and in this state it is generally found to combine with it a certain portion of dissolved animal oil or fat. Even without much increased action of the system, it is possible at times to obtain a knowledge of its existence under particular circumstances, or by particular applications. Thus, in cold subterraneous caverns, where the air is dense and

* In a paper on the Petiveria, in the Swedish Academy Transactions, there are a variety of curious observations on the peculiar properties given to the smell, flesh, &c. of different animals, in consequence of their feeding on different foods. It is entitled Petiveria, en Americansk växt. Anal. Trans. tom. i. p. 316.

heavy, the natural evaporation often escapes from the surface of the body in the form of thick clouds; and a bright mirror, when held near a warm and naked skin, in the temperature of the atmosphere, soon becomes obscured by a moist vapour.

The quantity of this fluid discharged, either in a state of quiescence or of increased action, has not been determined with any great degree of exactness. According to M. de Sauvages *, a man of middle stature and age, weighing 146 lbs., takes daily of food and drink about 56 ounces (circiter quinquaginta sex uncias), his dinner being about twice as much as his supper. In the same period he perspires about 28 ounces; viz. about twelve during the third part of his time in which he sleeps, and sixteen during the two-thirds in which he is awake. It appears certain, from the experiments of Gorter, that the weight of the body is more diminished by the same quantity of sweat than of mere perspiration.

Sanctorius, whose experiments of measuring the weight of the body were made in the warm climate of Italy, ascertained, that in that region eight pounds of food received by the mouth were, by the different insensible secretions, reduced to three; making the proportion of insensible exhalation as five to eight. In cold climates, however, it has been determined, that it does not amount to more than two-thirds of this pro-

* Nosol. Method. ii. 369.

portion; and of either quantity, it has lately been very satisfactorily established, that more than half this secretion has been thrown forth from the surface of the lungs; which I estimated in a previous lecture, and from the experiments and calculations of Lavoisier, as discharging not less than eleven ounces of solid carbone or charcoal in every four-and-twenty hours. *

Plants transpire precisely in the same way, and to a much greater extent, through the medium of their leaves; which, while they form a great part of their cuticle, may, as I have observed on a former occasion †, be also contemplated as their lungs. Hales calculated that a sun-flower, three feet high, transmits in twelve hours one pound four ounces of fluid by avoirdupois weight. Bishop Watson put an inverted glass vessel of the capacity of twenty cubic inches on grass which had been cut during a very intense heat of the sun, and after many weeks had passed without rain; in two minutes it was filled with vapour, which trickled with drops down its sides. He collected these on a piece of muslin, carefully weighed, and repeated the experiment for several days between twelve and three o'clock; and estimated, as the result of his experiment, that an acre of grass land transpires in twenty-four hours not less than 6,400 quarts of water. Dalton, for dew and rain together, makes the mean of England and

* Vol. I. Ser. I. Lect. XIII. † Vol. I. Ser. I. Lect. IX.

Wales '36 inches, thus amounting, in a year, to 28 cubic miles of water. Grew, in 1711, calculated the number of acres in South Britain at 46,800,000, and allowed a million to Holland. * Smith, for England alone, gives 73¼ millions in the present day. †

But the same general surface in animals and vegetables that thus largely secretes delicate fluids, largely also imbibes them by the corresponding system of absorbent vessels, opening with their spongy mouths or ducts in every direction. Hales ascertained that the above sun-flower, which threw off not less than twenty ounces of fluid in twelve hours, suspended its evaporation as soon as the dew fell, and absorbed two or three ounces of the dew instead. And among animals, and especially among mankind, the manifest operations of medicines, and other foreign substances, merely diffused through the air, or simply applied to the skin; of various vapours, as those of mercury, turpentine, and saffron; of various baths, as of tobacco, bitter-apple, opium, cantharides, arsenic, and other poisons, producing the most fatal effects, and altogether absorbed by the skin, are decisive and uncontrovertible proofs of such an action. It is hence the bradypus, or sloth, supports itself without drinking, perhaps at any time, and the ostrich and camel for very long periods, though the latter is also possest of a natural reservoir.

* Phil. Trans. for 1811, p. 265.

† Phil. Mag. xix. 197. Young's Nat. Phil. ii. 369.

And hence the chief impletion of the human body, in many cases of abdominal dropsy: since persons labouring under this disease have often been observed to fill with rapidity during the most rigid abstinence from drinks of every kind.

Along with the common odour of insensible perspiration, discharged from the human surface, we often meet with other odours of a much stronger kind, produced by particular diseases or particular modes of life, and which are distinctly perceptible. Thus, the food of garlic yields a perspiration possessing a garlic smell; that of peas a leguminous smell; coarse oils and fat a rancid smell, which is the cause of this peculiar odour among the inhabitants of Greenland; and acids a smell of acidity. Among glass-blowers, from the large quantity of sea-salt that enters into the materials of their manufacture, the sweat is sometimes so highly impregnated, that the salt they employ, and imbibe by the skin and lungs, has been seen to collect in crystals upon their faces.

Hence, too, the various smells that are emitted from the surface of other animals, and especially that of musk, which is one of the most common. We trace this issuing generally from the bodies of many of the ape species, and especially the simia *Jacchus*; still more profusely from the opossum, and occasionally from hedge-hogs, water-rats, hares, serpents, and crocodiles. The odour of civet is the production of the civet-cat

alone, the viverra *Zibetha*, and viverra *Civetta* of Linnéus; though we meet with faint traces of it in some varieties of the domestic cat, the felis *Catta* of the same writer. Genuine castor is, in in like manner, a secretion of the castor fiber; but the sus Tajassu, and various other species of swine, yield a smell that makes an approach towards it.

Among insects, however, these odours are considerably more varied, as well as considerably more pleasant; for the musk-scent of the cerambix *moschatus*, the apis *fragrans*, and the tipula *moschifera*, is far more delicate than that of the musk quadrupeds; while the cerambix *suaveolens*, and several species of the ichneumon, yield the sweetest perfume of the rose; and the petiolated sphex a balsamic ether highly fragrant, but peculiar to itself. Yet insects, like other classes of animals, furnish instances of disagreeable, and even disgusting scents, as well as of those that are fragrant. Thus, several species of the melitæ breathe an essence of garlic or onions; the staphilinus *brunipes* has a stench intolerably fetid, though combined with the perfume of spices; while the caterpillars of almost all the hymenoptera, and the larves of various other orders, emit an exhalation in many instances excessively pungent. The carabus *crepitans*, and sclopeta of Fabricius, pour forth a similar vapour, accompanied with a strange crackling sound.

The odorous secretions belonging to the vegetable tribes are well known to be still more variable: sometimes poured forth from the leaves of the plant, as in the bay, sweet-briar, and heliotrope; sometimes from the trunk, as in the pines and junipers; but more generally from the corol. It is from the minute family of the jungermannia, nearly related to the mosses, and often scarcely visible to the eye, that we derive the chief sense of that delightful fragrance perceptible after a shower, and especially at eventide *: and from the florets of the elegant anthoxanthum *odoratum*, or spring-grass, that we are chiefly furnished with the sweet and fragrant scent of new-mown hay. But occasionally the odours thus secreted are as intolerable as any that are emitted from the animal world; of which the ferula *assafœtida*, or assafetida plant, and the stapelia *hirsuta*, or carrion flower, are sufficient examples.

To the same secernent powers, moreover, of animals and vegetables, existing in particular organs rather than extended through the system generally, we are indebted for a variety of very valuable materials in trade and diet, as gums, resins, wax, fat, oils, spermaceti. And to the same cause we owe, also, the production of a multiplicity of poisons and other deleterious substances: such, for instance, as the poison of venomous serpents, which is found to consist of

* Hooker's Monography of British Jungerm.

a genuine gum, and is the only gum known to be secreted by animal organs; the electric gass of the gymnotus *electricus* and raia *Torpedo**; the pungent sting of the stinging-nettle, urtica *urens*, and of the bee, both which are produced from a structure of a similar kind; for every aculeus or stinging point of the nettle is a minute and highly irritable duct, that leads to a minute and highly irritable bulb, filled with a minute drop of very acrid fluid: and hence, whenever any substance presses against any of the aculei or stinging points of the plant, the impression is communicated to the bulb, which instantaneously contracts, and throws forth the minute drop of acrid fluid through the ducts upon the substance that touches them.

As the secernent system thus evidently allots particular organs for the secretion of particular materials, the absorbent system is in like manner only capable of imbibing and introducing into the general frame particular materials in particular parts of it. Thus, opium and alkohol, the juice of aconite, and essential oil of laurel or bitter almonds, produce little or no effect upon the absorbents of the skin, but a very considerable effect upon the coating of the stomach. In like manner, carbonic acid gass invigorates rather than injures, when applied to the absorbents of the stomach, but instantly destroys life when applied to those of the lungs; while the aroma of the toxicaria *Macasariensis*, or Boa upas, of which we have heard so much of

late years, proves equally a poison, whether received by the skin, the stomach, or the lungs.

So, also, substances that are poisonous to one tribe of animals are medicinal to a second, and even highly nutritive to a third. Thus, swine are poisoned by pepper-seeds, which to man are a serviceable and grateful spice; while henbane-roots, which destroy mankind, prove a wholesome diet to swine. In like manner, aloes, which to our own kind is a useful medicine, is a rank venom to dogs and foxes; and the horse, which is poisoned by the phellandrum *aquaticum*, or water-hemlock, and corrosive sublimate, will take a dram of arsenic daily, and improve hereby both in his coat and condition.

It has already appeared, that the secernent vessels of any part of the system, in order to accomplish a beneficial purpose, as, for example, that of restoring a destroyed or injured portion of an organ, may change their action, and secrete a material of a new nature and character. An equal change is not unfrequently produced under a morbid habit, and the secretion will then be of a deleterious instead of being of a healthy and sanative kind And hence, under the influence of definite causes, the origin of such mischievous and fatal secretions, in some instances thrown forth generally, and in others only from particular organs, as the matter of small-pox, measles, putrid fevers of various kinds, cancer, and hydrophobia, or the poisonous saliva of mad dogs.

But the field opens before us to an unbounded extent, and we should lose ourselves in the subject if we were to proceed much farther. It is obvious, that in organic, as in inorganic nature, every thing is accurately arranged upon a principle of mutual adaptation, and regulated by an harmonious antagonism, a system of opposite yet accordant powers, that balance each other with most marvellous nicety; that increase and diminution, life and death, proceed with equal pace; that foods are poisons, and poisons foods; and finally, that there is good enough in the world, if rightly improved, to make us happy in our respective stations so long as they are allotted to us, and evil enough to wean us from them by the time the grant of life is usually recalled.

LECTURE XV.

ON THE EXTERNAL SENSES OF ANIMALS.

The subject of study for the present lecture is the organs of external sense in animals: their origin, structure, position, and powers; and the diversities they exhibit in different kinds and species.

The external senses vary in their number: in all the more perfect animals they are five; and consist in the faculties of sight, smell, hearing, taste, and touch.

It is by these conveyances that the mind or sensory receives a knowledge of whatever is passing within or without the system; and the knowledge it thus gets possession of is called perception.

The different kinds of perception, therefore, are as numerous as the different channels through which they are received, and they produce an effect upon the sensory which usually remains for a long time after the exciting cause has ceased to operate. This effect, for want of a better term, we call *impressions;* and the particular facts, or things impressed, and of which

the impressions retain, as it were, the print or picture, *ideas.*

The sensory has a power of suffering this effect or these ideas to remain latent or unobserved, and of calling them into observation at its option: it is the active exercise of this power that constitutes *thought.*

The same constitution, moreover, by which the mind is enabled to take a review of any introduced impression, or to exercise its thought upon any introduced idea, empowers it to combine such impressions or ideas into every possible modification and variety. And hence arises an entirely new source of knowledge, far more exalted in its nature, and infinitely more extensive in its range: hence memory and the mental passions; hence reason, judgment, consciousness, and imagination, which have been correctly and elegantly termed the *internal senses*, in contradistinction to those by which we obtain a knowledge of things exterior to the sensorial region.

Thus far we can proceed safely, and feel our way before us; but clouds and darkness hang over all beyond, and a gulf unfathomable to the plummet of mortals. Of the sensory, or mind itself, we know nothing; we have no chemical test that can reach its essence, no glasses that can trace its mode of union with the brain, no abstract principles that can determine the laws of its control. We see, however, enough to convince us that its powers are of a very different

description from those of the body, and revelation informs us that its nature is so too. Let us receive the information with gratitude, and never lose sight of the duties it involves.

But this subject would lead us astray even at our outset: it is important, and it is enticing; and the very shades in which much of it is wrapped up prove an additional incitement to our curiosity. It shall form the basis of some subsequent investigation *, but our present concern is with the external senses alone.

These, for the most part, issue from the brain, which, in all the more perfect animals, is an organ approaching to an oval figure; and consists of three distinct parts: the cerebrum, or brain properly so called; the cerebel, or little brain, and the oblongated marrow. The first constitutes the largest and uppermost part; the second lies below and behind; the third, level with the second, and in front of it — it appears to issue equally out of the two other parts, and gives birth to the spinal marrow, which may hence be regarded as a continuation of the brain, extended through the whole chain of the spine or back-bone.

From this general organ arises a certain number of long, whitish, pulpy strings or bundles of fibres, capable of being divided and subdivided into minuter bundles of filaments or still smaller fibres, as far as the power of glasses can carry

* Vol. III. Series III. Lect. I. II. III. IV.

the eye. These strings are denominated nerves; and by their different ramifications convey different kinds or modifications of sensation to different parts of the body, keep up a perpetual communication with its remotest organs, and give activity to the muscles. They have been supposed by earlier physiologists to be tubular or hollow, and a few experiments have been tried to establish this doctrine in the present day, but none that have proved satisfactory.

As the brain consists of three general divisions, it might, at first sight, be supposed that each of them is allotted to some distinct and ascertainable purpose: as, for example, that of forming the seat of intellect, or thinking; the seat of the local senses of sight, sound, taste, and smell; and the seat of general feeling or motivity. But the experiments of anatomists upon this abstruse subject, numerous and diversified as they have been of late years, and, unhappily, upon living as well as upon dead animals, have arrived at nothing conclusive in respect to it; and have rather given rise to contending than to concurrent opinions. So that we are nearly or altogether unacquainted with the reason of this conformation, and of the respective share which each division takes in producing the general effect.

The nerves uniformly issue in pairs, one for each side of the body, and the number of the pairs is thirty-nine; of which nine rise immediately from the great divisions of the brain,

under which we have just contemplated it, and are chiefly appropriated to the four local senses; and thirty from the spinal marrow, through different apertures in the bone that encases it, and are altogether distributed over the body, to produce the fifth or general sense of touch and feeling, as also irritability to the muscles.

That these nervous or pulpy fibres are the organs by which the various sensations are produced or maintained is demonstrable from the following facts. If we divide, or tie, or merely compress a nerve of any kind, the muscle with which it communicates becomes almost instantly palsied; but upon untying or removing the compression the muscle recovers its feeling and mobility. If the compression be made on any particular portion of the brain, that part of the body becomes motionless which derives nerves from the portion compressed. And if the cerebrum, cerebel, or oblongated marrow be irritated, excruciating pain or convulsions, or both, take place all over the body, though chiefly where the irritation is applied to the last of these three parts.

The matter of sensation, or nervous fluid, as for want of a more precise knowledge upon this subject we must still continue to call it, is probably as homogeneous in its first formation as the fluid of the blood; but, like the blood, it appears to be changed by particular actions, either of particular parts of the brain, or of the particular nervous fibres themselves, into fluids

of very different properties, and producing very different results. And it is probably in consequence of such changes alone that it is capable of exciting one set of organs to communicate to the brain the sensation of sound alone, another set that of sight alone, and so of the rest. While branches from the spinal marrow, or fountain-nerve of touch, are diffused over every portion of the body, sometimes in conjunction with the local nerves, as in the organs of local sense, and sometimes alone, as in every other part of the system. *

Such an idea leads us naturally to a very curious and recondite subject, which has never, that I know of, been attended to by physiologists, and will at the same time throw no small degree of light upon it: — I mean the production of other senses and sensorial powers than are common to the more perfect animals, or such a modification of some one of them as may give the semblance of an additional sense.

What, for example, is that wonderful power by which migratory birds and fishes are capable of steering with the precision of the expertest mariner from climate to climate, and from coast to coast; and which, if possest by man, might perhaps render superfluous the use of the magnet, and considerably infringe upon the science of logarithms? Whence comes it that the field-fare and red-wing, that pass their summers in Norway,

* See Hunter's Anim. Economy, p. 261, 262.

or the wild-duck and merganser, that in like manner summer in the woods and lakes of Lapland, are able to track the pathless void of the atmosphere with the utmost nicety, and arrive on our own coasts uniformly in the beginning of October? or that the cod, the whiting, and the herring, should visit us in innumerable shoals from quarters equally remote, and with an equal exactness of calculation? the cod pursuing the whiting, which flies before it, from the banks of Newfoundland to the southern coasts of Spain; and the cachalot, or spermaceti whale, driving vast armies of herrings from the arctic regions, and devouring thousands of those that are in the rear every hour.

We know nothing of this sense, or the means by which all this is produced: and knowing nothing of it, and feeling nothing of it, we have no terms by which to reason concerning it.

Yet it is a sense not limited to migratory animals. A carrier-pigeon has been brought in a bag from Norwich to this metropolis, constituting a distance of 120 miles; and having been let off with a letter tied round its neck, from the top of St. Paul's, has returned home through the air in a straight line, in four or five hours.

Buffon asserts, that a hawk or eagle can travel two hundred leagues in ten hours, and relates a story of one that travelled two hundred and fifty leagues in sixteen hours.

A Newfoundland dog has in like manner been

brought from Plymouth to London by water, and having got loose, has run home by land with a speed so rapid as to prove that his course must have been nearly in a straight line, though every inch of it was unknown to him.

At such instances we start back, and as far as we can, we disbelieve them, and think we become wise in proportion as we become sceptical. Meanwhile nature pursues her wonder-working course, equally uninfluenced by our doubts or our convictions. *

Even among mankind, however, we occasionally meet with a sort of sensation altogether as wonderful and inexplicable. For there are some persons so peculiarly affected by the presence of a particular object, that is neither seen, smelt, tasted, heard, or touched, as not only to be

* The fact of the migratory power of one kind of animals confirms the fact of the migratory power of others. While the question was confined to birds it was too often denied by many naturalists, merely from the difficulty of accounting for it; and it was said, in opposition to Catesby and White, and all our best ornithologists, that our summer birds only disappear by creeping into holes and crevices to hybernate. And hence, even so late as 1823, the late Dr. Jenner felt himself called upon to examine such assertions with a view of disproving them; which he has done in one of the most agreeable essays on the natural history of migratory birds to be found in our own or any other language. " A little reflection," says he, " must compel us to confess that they are endowed with discriminating powers totally unknown to, and for ever unattainable by man. I have no objection to admit the possibility that birds may be overtaken by the cold of winter, and thus

conscious of its presence, but to be in an agony till it is removed. The vicinity of a cat not unfrequently produces such an effect; and I have been a witness to the most decisive proofs of this in several instances. It is possible that the anomalous sense may in this instance result from a peculiar irritability in some of the nervous branches of the organ of smell, which may render them capable of being irritated in a new and peculiar manner: but the persons thus affected are no more conscious of an excitement in this organ of sense than in any other; and from the originality of the sensation itself find no terms in any language by which the sensation can be expressed.

Sharks and rays are generally supposed by naturalists to be endowed with a peculiar sense

be thrown into the situation of other animals which remain torpid at that season; though I must own I never witnessed the fact, nor could I ever obtain evidence on the subject that was to me satisfactory; but, as it has been often asserted, may I be allowed to suppose that some deception might have been practised with the design of misleading those to whom it might seem to have appeared obvious?" Phil. Trans. 1824, p. 11. The strongest argument against all such disbelief, arising from the difficulty of accounting for the migration of birds, is to turn to the migration of fishes, and to the parallel cases of remote travel in other animals, which are given above. The respective marvels give support to each other, till disbelief itself becomes at length the greatest marvel of the whole.

in the organ of a tubular structure found immediately under the integuments of the head, though they have not agreed as to the exact character of this additional sense. Trevannius calls it generally a sixth organ of sensation. M. Jacobson, and Dr. de Blainville, who quotes his authority, regard it as a local organ of touch. M. Roux, who seems to have examined it with great attention, believes it to be the source of a feeling of a middle nature between the two senses of touch and hearing.* The bat appears to have, in like manner, an additional sensific power, for it is observed to avoid external objects when in their vicinity, while the eye, ear, and nose are closed, and there is no direct touch: and this peculiar feeling has been called a sixth sense generally by naturalists, without discriminating it farther.

What is the cause of those peculiar sensations which we denominate hunger and thirst? A thousand theories have been advanced to account for them, but all have proved equally unsatisfactory, and have died one after another almost as soon as they have received a birth. We trace indeed the organs in which they immediately reside, and know by the sensations themselves that the one exists in the region of the stomach, and the other in that of the throat: but though we call them sensations, they have neither of

* See further on this subject. Edinb. Journ. of Science, No. III. Art. III p. 87, 1825.

them any of the common characters of touch, taste, hearing, seeing, or smelling.

Foods and drinks are the natural and common means of quieting their pain, but there are other means that may be also employed for this purpose, and which are often found to answer as a temporary substitute: as, for instance, pressure against the coats of the stomach in the case of hunger, and stimulating the salivary glands in the case of thirst. It is hence that chewing a mouthful of hay alone, or merely moistened with water, proves so refreshing to a tired horse, and is found so serviceable when we dare not allow him to slake his thirst by drinking. Savages and savage beasts are equally sensible of the advantage of pressure in the case of hunger, and resort to it upon all occasions in which they cannot take off the pain in the usual way.

The manis or pangolin tribes, that swallow their food whole, will swallow stones or coals or any other substance, if they cannot obtain nutriment: not that their instinct deceives them, but for the purpose of acquiring such a pressure as may blunt the sense of hunger, which is found so corroding. Almost all carnivorous beasts pursue the same plan; and a mixture of pieces of coal, stone, slate, and earth, is often met with in the stomach of ostriches, cassowaries, and even toads. The Kamschadale obtains the same purpose by swallowing saw-dust; and some of the northern Asiatic tribes by a board placed over the region of the stomach, and tightened behind

with cords, in proportion to the severity of the suffering. Even in our own country we often pursue the same end by the same means; and employ a tight handkerchief, instead of a tightened stomach-board.

In consequence of this difference in the mode in which the matter of touch or general feeling is secreted under different circumstances, we may also perceive why some parts of the body, although perhaps as largely furnished with the nerves of touch or general feeling as other parts, are far less sensible and irritable, as the bones, the teeth, and the tendons: and why the very same parts should, under other circumstances, as when morbidly affected, become the most sensible or irritable of all the organs of the system, a fact well known to all, but I believe not hitherto satisfactorily accounted for by any one.

We may see also why inflammation, attacking different organs of the body, should be accompanied with very different sensations. In the bones and cartilages, except in extreme cases, it is accompanied with a dull and heavy pain; in the brain, with an oppressive and stupifying pain; and in the stomach, with a nauseating uneasiness. So, again, in the skin, muscles, and cellular membrane, it is a pain that rouses and excites the system generally; but in those parts which are supplied with the two branches of nerves which are called par vagum and sympathetic, as the loins and kidneys, the patient is

affected with lowness of spirits from the first attack of the inflammation.*

Dr. Gall, whose physiological theory has excited so much attention of late years on the Continent, has endeavoured to account for all these varieties of feeling, and, indeed, for all the animal senses of every kind, both external and internal, by supposing some particular part of the brain to be allotted to each, and that the general character and temperament of the individual is the result of the different proportions which these different parts or chambers of the brain bear to one another. He supposes, also, that this organ is possessed of two distinct sets of nervous fibres—a secernent and an absorbent: both directly connected with what is called the cineritious or ash-coloured part of the brain; the former issuing from it and secreting the fluid of the will, or that by which the mind operates on the muscles; and the latter terminating in it, and conveying to it the fluid of the external senses, secreted by those senses themselves, and communicating a knowledge of the presence and degree of power of external objects. This elaborate theory, and the facts to which it appeals, were very minutely investigated a few years ago by a very excellent committee of the physical class of the French National Institute, assisted by Mr. (now Dr.) Spurzheim, the intimate friend and coadjutor of its inventor, and

* Hunter on Blood, p. 289, 290.

who is well known to have contributed quite as much to the establishment of this speculation as himself. This committee, after a very minute and cautious research, gave it as a part of their report, that the doctrine of the origin and action of the nerves is probably correct; but that this doctrine does not appear to have any immediate or necessary connexion with that part of Dr. Gall's theory which relates to distinct functions possessed by distinct parts of the brain. The origin, and distribution, and action, however, of the nervous trunks have since been far more accurately traced out by Mr. Charles Bell, M. Magendie, and various other physiologists; while, in refutation of the doctrine that ascribes distinct functions to distinct parts of the brain, it may be sufficient to observe, for the present, that many of the nerves productive of different functions originate in the same part, while others, productive of the same function, originate in different parts.

There is no animal whose brain is a precise counterpart to that of man; and it has hence been conceived, that by attending to the distinctions between the human brain and that of other animals, we might be able to account for their different degrees of intelligence. But the varieties are so numerous, and the parts which are deficient in one animal are found connected

* For an examination of the general subject of craniology and physiognomy, see Vol. III. Ser. III. Lect. XIII.

with such new combinations, modifications, and deficiencies in others, that it is impossible for us to avail ourselves of any such diversities. Aristotle endeavoured to establish a distinction by laying it down as a maxim that man has the largest brain of all animals in proportion to the size of his body; a maxim which has been almost universally received from his own time to the present period. But it has of late years, and upon a more extensive cultivation of comparative anatomy, been found to fail in various instances: for while the brain of several species of the ape kind bears as large a proportion to the body as that of man, the brain of several kinds of birds bears a proportion still larger. M. Sömmering has carried the comparison through a great diversity of genera and species: but the following brief table will be sufficient for the present purpose. The weight of the brain to that of the body, forms —

In man, from $\frac{1}{22}$ to $\frac{1}{33}$ part.
— several tribes of simia $\frac{1}{22}$ —
— dog - - $\frac{1}{161}$ —
— elephant - - $\frac{1}{500}$ —
— sparrow - - $\frac{1}{25}$ —
— canary bird - $\frac{1}{14}$ —
— goose - - $\frac{1}{360}$ —
— turtle (smallest) - $\frac{1}{5688}$ —

M. Sömmering has hence endeavoured to correct the rule of Aristotle by a modification, under which it appears to hold universally; and

thus corrected, it runs as follows: "Man has the largest brain of all animals in proportion to the general mass of nerves that issue from it."

Thus, the brain of the horse gives only half the weight of that of a man, but the nerves it sends forth are ten times as bulky. The largest brain which M. Sömmering ever dissected in the horse tribe weighed only 1 lb. 4oz., while the smallest he ever met with in an adult man was 2 lb. 5½ oz.*

It is a singular circumstance, that in the small heart-shaped pulpy substance of the human brain, denominated the pineal gland, and which Descartes regarded as the seat of the soul, a collection of sandy matter should invariably be found after the first few years of existence; and it is still more singular that such matter has rarely, if ever, been detected but in the brain of a few bisulcated animals, as that of the fallow-deer, in which it has been found by Sömmering †; and that of the goat, in which it has been traced by Malacarne.‡

The nervous system of all the vertebral or first four classes of animals, — mammals, birds, amphibials, and fishes, — are characterised by the two following properties: — first, the organ

* Stud. of Med. iv. 11. 2d edit.

† Dissertatio de basi Encephali, 1778; and Tabula bas. os Encephali, 1799. See Blumenb. p. 292.

‡ Dissert. p. 10. See also Blumenbach, Anat. Comp § 206.

of sense consists of a gland or ganglion, with a long and bifid chord or spinal marrow descending from it, of a smaller diameter than the gland itself; and, secondly, both are severally inclosed in a bony case or covering.

In man, as we have already observed, this gland, or ganglion, is (with a few exceptions) larger than in any other animal, in proportion to the size of the body; without any exception whatever in proportion to the size of the chord or spinal marrow that issues from it.

In other animals, even of the vertebral classes, or those immediately before us, we meet with every variety of proportion; from the ape, which, in this respect, approaches nearest to that of man, to tortoises and fishes, in which the brain or ganglion does not much exceed the diameter of the spinal marrow itself.

It is not therefore to be wondered at that animals of a still lower description should exhibit proofs of a nervous chord or spinal marrow, without a superior gland or brain of any kind; and that this chord should even be destitute of its common bony defence. And such is actually the conformation of the nervous system in insects, and, for the most part, in worms; neither of which are possessed of a cranium or spine, and in none of which we are able to trace more than a slight enlargement of the superior part of the nervous chord, or spinal marrow, as it is called in other animals—a part situated near the mouth,

and apparently intended to correspond with the organ of a brain. The nervous chord, however, in these animals is, for the most part, proportionally larger than in those of a superior rank; and at various distances is possessed of little knots or ganglions, from which fresh ramifications of nerves shoot forth, like branches from the trunk of a tree, and which may perhaps be regarded as so many distinct cerebels or little brains.

In zoophytic worms, we can scarcely trace any distinction of structure, and are totally unable to recognise a nervous system of any kind. The common and almost transparent hydra or polype, which is often to be found in the stagnant waters of our own country, with a body about an inch long, and arms or tentacles in propo tion, appears to consist, when examined by the best glasses, of nothing but a granular structure, something like boiled sago, connected by a gelatinous substance into a definite form.* Hydatids and infusory animals exhibit a similarity of make. The common formative principle of all these may be reasonably conjectured to consist in the living power of the blood alone, or rather of the fluid which answers the purpose of blood; and their principles of action to be little more than instinctive.

Can we, then, conceive that all these different kinds, and orders, and classes of animals, thus differently organized and differently endowed

* Blumenb. Anat. Comp. § 203.

with intelligence, are possessed of an equality of corporeal feeling? or, to adopt the language of the poet, that—

> the poor worm thou tread'st on,
> In corporal suffering, feels a pang as great
> As when a giant dies?

This is an interesting question, and deserves to be examined at some length. It may, perhaps, save the heart of genuine sensibility from a few of those pangs which, even under the happiest circumstances of life, will be still called forth too frequently; and if there be a human being so hardened and barbarized as to take advantage of the conclusion to which the enquiry may lead us, he will furnish an additional proof of its correctness in his own person, and show himself utterly unqualified for the discussion.

Life and sensation, then, are by no means necessarily connected: the blood is alive, but we all know it has no sensation; and vegetables are alive, but we have no reason to suppose they possess any. Sensation, so far as we are able to trace it, is the sole result of a nervous structure. Yet, though thus limited, it has already appeared that it does not exist equally in every kind of the same structure, nor in every part of the same kind. The skin is more sensible to pain than the lungs, the brain, or the stomach; but even the skin itself is more sensible in some parts than in others, which are apparently supplied with an equal number of nerves, and of

nerves from the very same quarter. It is perhaps least sensible in the gums; a little more so on the hairy scalp of the head; much more so on the front of the body; and most of all so in the interior of the eyelids: while the bones, teeth, cartilages, cuticle, and cellular membrane, though largely supplied with nerves, have no sensation whatever in a healthy state.

As the degree of intelligence decreases, we have reason to believe that the intensity of touch or corporeal feeling decreases also, excepting in particular organs, in which the sense of touch is employed as a local power. And hence we may reasonably conjecture that in some of the lowest ranks of animals, the sensibility may not exceed, even in their most lively organs, the acuteness of the human cellular membrane, cuticle, or gums.

This, however, does not rest upon conjecture or even upon loose indefinite reasoning. We find in our own system that those parts which are most independent of all the other parts, and can reproduce themselves most readily, are possest of the smallest portion of sensation; such are all the appendages of the true skin, the cuticle, horn, hair, beard, and nails: some of which are so totally independent of the rest, that they will not only continue to live but even to grow for a long time after the death of every other part of the body.

Now it is this very property by which every kind of animal below the rank of man is in a greater or less degree distinguished from man

himself. All of them are compounded of organs which in a greater or less degree approach towards that independence of the general system which, in man, the insensible or less sensible parts alone possess: and hence all of them are capable of reproducing parts that have been destroyed by accident or disease, with vastly more facility and perfection than mankind can do.

I have once or twice had occasion to apply this remark to the lobster, which has a power not only of reproducing its claws spontaneously, when deprived of them by accident or disease, but of throwing them off spontaneously whenever laid hold of by them, in order to extricate itself from the imprisoning grasp. The tipula *pectiniformis*, or insect vulgarly called father-long-legs, and several of the spider family, are possest of a similar power, and exercise it in a similar manner. These limbs are renewed by the formative effect of the living principle in a short period of time: but it would be absurd to imagine that in thus voluntarily parting with them the animal puts himself to any very intolerable degree of pain; for in such case he would not exert himself to throw them off. The gad-fly, when it has once fastened on the hand, may be cut to pieces apparently without much disturbance of its gratification; and the polype appears to be in as perfect health and contentment when turned inside out as when in its natural state. This animal may be divided into halves, and each half by its own formative and instinctive effort will produce the half that is deficient, and in

this manner an individual of the tribe may be multiplied into countless numbers.

In many animals of the three classes of amphibials, insects, and worms, the most dreadful wounds that can be inflicted, unless actually mortal, seem hardly to accelerate death: and hence we have a decisive proof that the pain endured by such animals must be very considerably and almost infinitely less than would be suffered by animals of a more perfect kind, and especially by man; since in these the pain itself, and the sympathetic fever which follows as its necessary result, would be sufficient to kill them independently of any other cause.

The life of man is in jeopardy upon the fracture or amputation of a limb; and even at times when his body has been spattered over with a charge of small shot, or only of gunpowder. But M. Ribaud, with a spirit of experimenting that I will not justify, has stuck different beetles through with pins, and cut and lacerated others in the severest manner, all of which lived through their usual term of life as though no injury had been committed on them. Vaillant wishing to preserve a locust of the Cape of Good Hope, took out the intestines, and filled the abdomen with cotton, and then fixed it down by a pin through the chest; yet after five months the animal still moved its feet and antennas.

In the beginning of November Redi opened the skull of a land tortoise, and excavated it of the whole brain. He expressly tells us that the

tortoise did not seem to suffer: it moved about as before, but groped for its path, for the eyes closed soon after losing the brain, and never opened again. A fleshy integument was produced, which covered the opening of the skull, but the instinctive power of the living principle was incompetent to renew the brain, and in the ensuing May, six months afterwards, the animal died. *

Spalanzani has incontestibly proved that the snail has a power of reproducing a new head when decapitated: but it should be remarked that the brain of the snail does not exist in its head.

I will not pursue this argument any farther; it is in many respects painful and abhorrent; and consists of experiments in which I never have been, and trust I never shall be, a participant. But I avail myself of the facts themselves in order to establish an important conclusion in physiology, which I could not so well have established without them.

Let us turn to a more cheerful subject, and examine a few of those peculiarities in the external senses which characterize the different classes and orders of animals, so far as we are acquainted with such distinctions; and admire the wisdom which they display.

The only sense which seems common to animals, and which pervades almost the whole surface of their bodies, is that of general touch or feeling, whence M. Cuvier supposes that

* Dalzell's Introd. to his Transl. of Spalanzani, p. xlv.

the material of touch is the sensorial power in its simplest and uncompounded state; and that the other senses are only modifications of this material, though peculiarly elaborated by peculiar organs, which are also capable of receiving more delicate impressions.* Touch, however, has its peculiar local organ, as well as the other senses, for particular purposes, and purposes in which unusual delicacy and precision are required; in man this peculiar power of touch is well known to be seated in the nervous papillæ of the tongue, lips, and extremities of the fingers. Its situation in other animals I shall advert to presently.

The differences in the external senses of the different orders and kinds of animals consist in their number and degree of energy,

All the classes of vertebral animals possess the same number of senses as man. Sight is wanting in zoophytes, in various kinds of molluscous and articulated worms, and in the larves of several species of insects. Hearing does not exist, or at least has not been traced to exist, in many molluscous worms and several insects in a perfect state. Taste and smell, like the general and simple sense of touch, seem seldom to be wanting in any animal.

The local sense of TOUCH, however, or that which is of a more elaborate character and capable of being exercised in a higher degree,

* Anatom. Comparat. i 25.

appears to be confined to the three classes of mammals, birds, and insects: and even in the last two it is by no means common to all of them, and less so among insects than among birds.

In apes and macaucoes, constituting the quadrumana of Blumenbach, it resides partly in the tongue, and tips of the fingers, as in man, but equally, and in some species even in a superior degree, in their toes. In the racoon (ursus *lotor*) it exists chiefly in the under surface of the front toes. In the horse, and cattle orders, it is supposed by most naturalists to exist conjointly in the tongue and snout, and in the pig and mole to be confined to the snout alone; this however is uncertain; as it is also, though there seems to be more reason for such a belief, that in the elephant it is seated in the proboscis. Some physiologists have supposed the bristly hairs of the tiger, lion, and cat, to be an organ of the same kind; but there seems little ground for such an opinion. In the opossum (and especially the Cayenne opossum) it exists very visibly in the tail; and M. Cuvier suspects that it has a similar existence in all the prehensile-tailed mammals.

Blumenbach supposes the same sense to have a place in the same organ in the platypus or ornithorhynchus as he calls it, that most extraordinary duck-billed quadruped which has lately been discovered in Australia, and, by its inter-

mixture of organs, confounds the different classes of animals, and sets all natural arrangement at defiance.

The local organ of touch or feeling in ducks and geese, and some other genera of birds, appears to be situated in the integument which covers the extremity of the mandibles, and especially the upper mandible, with which apparatus they are well known to feel for their food in the midst of mud in which they can neither see nor perhaps smell it.

We do not know that amphibials, fishes, or worms possess any thing like a local sense of touch; it has been suspected in some of these, and especially in the arms of the cuttle-fish, and in the tentacles of worms that possess this organ, but at present it is suspicion and nothing more.

In the insect tribes, we have much reason for believing such a sense to reside in the antennas, or in the tentacles; whence the former of these are denominated by the German naturalists *fühlhorner* or feeling-horns. This belief has not been fully established, but it is highly plausible, from the general possession of the one or the other of these organs by the insect tribes, the general purpose to which they apply them, and the necessity which there seems for some such organ from the crustaceous or horny texture of their external coat.

The senses of TASTE and SMELL in animals bear a very near affinity to the local sense of

touch; and it is difficult to determine whether the upper mandible of the duck tribe, with which they distinguish food in the mud, may not be an organ of taste or smell as well as of touch; and there are some naturalists that in like manner regard the cirrous filaments or antennules attached to the mouths of insects as organs of taste and touch equally. Taste in the more perfect animals resides jointly in the papillæ of the tongue and the palate; but I have already had occasion to observe that it may exist, and in full perfection, in the palate alone, since it has been found so in persons who have completely lost the tongue from external force or disease.

In animals that possess the organ of nostrils this is always the seat of smell; and in many quadrupeds, most birds, and perhaps most fishes, it is a sense far more acute than in man, and that which is chiefly confided in. For the most part it resides in the nerves distributed over a mucous membrane that lines the interior of the bones of the nostrils, and which is called the Schneiderian membrane, in honour of M. Schneider, a celebrated anatomist, who first accurately described it. Generally speaking, it will be found that the acuteness of smell bears a proportion in all animals to the extent of surface which this membrane displays; and hence, in the dog and cattle tribes, as well as in several others, it possesses a variety of folds or convolutions, and in birds is continued to the utmost points of the

nostrils, which in different kinds open in very different parts of the mandible.

The frontal sinuses, which are lined with this delicate membrane, are larger in the elephant than in any other quadruped, and in this animal the sense is also continued through the flexible organ of its proboscis. In the pig the smelling organ is likewise very extensive; and in most of the mammals possessing proper horns it ascends as high as the processes of the frontal bone from which the horns issue.

It is not known that the cetaceous tribes possess any organ of smell; their blowing-holes are generally regarded as such; but the point has been by no means fully established. We are in the same uncertainty in respect to amphibials and vorms; the sense is suspected to exist in all the former, and in several of the latter, especially in the cuttle-fish, but no distinct organ has hitherto been traced out satisfactorily.

In fishes there is no doubt; the olfactory nerves are very obviously distributed on an olfactory membrane, and in several instances the snouts are double, and consequently the nostrils quadruple, a pair for each snout. This powerful inlet of pleasure to fishes often proves fatal to them from its very perfection; for several kinds are so strongly allured by the odour of marjorum, assafœtida, and other aromas, that by smearing the hand over with these substances, and immersing it in the water, they will often

flock towards the fingers, and in their intoxication of delight may easily be laid hold of. And hence the angler frequently overspreads his baits with the same substances, and thus arms himself with a double decoy.

There can be no doubt of the existence of the same sense in insects, for they possess a very obvious power of distinguishing the odorous properties of bodies, even at a considerable distance beyond the range of their vision: but the organ in which this sense resides has not been satisfactorily pointed out; Reimai supposes it to exist in their stigmata, and Knoch in their anterior pair of feelers.

The general organ of HEARING is the ear, but not always so; for in most of those who hear by the Eustachian tube only, it is the mouth, and in the whale tribes the nostrils or blow-hole. It is so, however, in all the more perfect animals, which usually for this purpose possess two distinct entrances into the organ, a larger and external, surrounded by a lobe; and a smaller and internal, opening into the mouth. It is this last which is denominated the Eustachian tube. The shape of the lobe is seldom found even in mammals similar to that in man, excepting among the monkey and the porcupine tribes. In many kinds there is neither external lobe nor external passage. Thus, in the frog, and most amphibious animals, the only entrance is the internal, or that from the mouth; and in the

cetaceous tribes the only effective entrance is probably of the same kind; for, though these may be said to possess an external aperture, it is almost imperceptibly minute. It is a curious fact, that, among the serpents, the blind-worm or common harmless snake is the only species that appears to possess an aperture of either sort; the rest have a rudiment of the organ within, but we are not acquainted with its being pervious to sound.

Fishes are well known to possess a hearing organ, and the skate and shark have the rudiment of an external ear; but, like other fishes, they seem chiefly to receive sound by the internal tubule alone.

That insects in general hear is unquestionable, but it is highly questionable by what organ they obtain the sense of hearing. The antennas, and perhaps merely because we do not know their exact use, have been supposed by many naturalists to furnish the means; it appears fatal, however, to this opinion to observe, that spiders hear though they have no true antennas, and that other insects which possess them naturally seem to hear as correctly after they are cut off.

The sense of VISION exhibits perhaps more variety in the different classes of animals than any of the external senses. In man, and the greater number of quadrupeds, it is guarded by an upper and lower eye-lid; both of which in man, but neither of which in most quadrupeds,

are terminated by the additional defence and ornament of cilia or eye-lashes. In the elephant, opossum, seal, cat kind, and various other mammals, all birds, and all fishes, we find a third eye-lid, or nictitating membrane, as it is usually called, arising from the internal angle of the eye, and capable of covering the pupil with a thin transparent veil, either wholly or in part, and hence of defending the eyes from danger in their search after food. In the dog this membrane is narrow; in oxen and horses it will extend over half the eye-ball; in birds it will easily cover the whole; and it is by means of this veil, according to Cuvier, that the eagle is capable of looking directly against the noon-day sun. In fishes it is almost always upon the stretch, as in their uncertain element they are exposed to more dangers than any other animal. Serpents have neither this nor any other eye-lid; nor any kind of external defence whatever but the common integument of the skin.

The largest eyes in proportion to the size of the animal belong to the bird tribes, and nearly the smallest to the whale; the smallest altogether to the shrew and mole; in the latter of which the eye is not larger than a pin's head.

The iris, with but few exceptions, partakes of the colour of the hair, and is hence perpetually varying in different species of the same genus. The pupil exhibits a very considerable, though not an equal, variety in its shape. In man it is

circular; in the lion, tiger, and indeed all the cat kind, it is oblong; transverse in the horse and in ruminating animals; and heart-shaped in the dolphin.

In man, and the monkey tribes, the eyes are placed directly under the forehead; in other mammals, birds, and reptiles, more or less laterally; in some fishes, as the genus pleuronectes, including the turbot and flounder tribes, both eyes are placed on the same side of the head; in the snail they are situated on its horns, if the black points on the extremities of the horns of this worm be real eyes, of which, however, there is some doubt; in spiders the eyes are distributed over different parts of the body, and in different arrangements, usually eight in number, and never less than six. The eyes of the sepia have lately been detected by M. Cuvier; their construction is very beautiful, and nearly as complicated as that of vertebrated animals. * Polypes and several other zoophytes appear sensible of the presence of light, and yet have no eyes; as the nostrils are not in every animal necessary to the sense of smell, the tongue to that of taste, or the ears to that of sound. A distinct organ is not always requisite for a distinct sense. In man himself we have already seen this in regard to the sense of touch, which exists both locally and generally; the distinct

* Le Règne Animale distribué d'apres son Organization, 4 tomes, 8vo, Paris, 1817.

organ of touch is the tips of the tongue and of the fingers, but the feeling is also diffused, though in a subordinate and less precise degree over every part of the body. It is possib therefore, in animals that appear endowed wi particular senses without particular organs fo their residence, that these senses are diffused like that of touch, over the surface generally: though there can be no doubt that, for want o. such appropriate organs, they must be less acute and precise than in animals that possess them. *

But who of us can say what is possible? who of us can say what has actually been done? After all the assiduity with which this attractive science has been studied, from the time of Aristotle to that of Lucretius, or of Pliny, and from these periods to the present day,—after all the wonderful and important discoveries which have been developed in it, natural history is even yet but little more than in its infancy, and zoonomy is scarcely entitled to the name of a science in any sense. New varieties and species, and even kinds of beings, are still arising to our view among animals, among vegetables, among minerals:—new structures are detecting in those already known, and new laws in the application of their respective powers.

But the globe has been upturned from its foundation; and with the wreck of a great part

* Stud. of Med. Vol. iv. p. 14. edit. 2d, 1825.

of its substance has intermingled the wreck of a great part of its inhabitants. It is a most extraordinary fact, that of the five or six distinct layers or strata of which the solid crust of the earth is found to consist, so far as it has ever been dug into, the lowermost, or granitic, as we observed on a former occasion *, contains not a particle of animal or vegetable materials of any kind; the second, or transition formation, as Werner has denominated it, is filled, indeed, with fossil relics of animals, but of animals not one of which is to be traced in a living state in the present day; and it is not till we ascend to the third, or floetz stratification, that we meet with a single organic remain of known animal structures.

M. Cuvier has been engaged for the last fifteen years in forming a classification, and establishing a museum of nondescript animal fossils, for the purpose of deciding, as far as may be, the general nature and proportion of those tribes that are now lost to the world: and in the department of quadrupeds alone, his collection of unknown species amounted in the year 1810 to not less than seventy-eight, some of which he has been obliged to arrange under new genera, as we shall have occasion to notice still further in a subsequent study. In the new and untried soil of America, the bones of unknown kinds and species lie buried in profusion; and my late

* Vol. I. Ser. I. Lect. VI. p. 132.

friend, Professor Barton, of Philadelphia, one of our first transatlantic physiologists, informed me by letter a short time before his death, that they are perpetually turning up skeletons of this description, whose living representatives are no where to be met with.

In few words, every region has been enriched with wonders of animal life that have long been extinct for ever. Where is now that enormous mammoth, whose bulk outrivalled the elephant's * ? where that gigantic tapir, of a structure nearly as mountainous *, whose huge skeleton has been found in a fossil state in France and Germany; whilst its only living type, a pigmy of what has departed, exists in the wilds of America ? where is now the breathing form of the fossil sloth of America, the magalonix of Cuvier, whose size meted that of the ox * ? where the mighty monitor *, outstripping the lengthened bulk of the crocodile ? itself too, a lord of the ocean, and yet, whose only relics have been traced in the quarries of Maestricht; to which, as to another leviathan, we may well apply the forcible description of the Book of Job, " at whose appearing the mighty were afraid, and who made the deep to boil as a cauldron: who esteemed iron as straw, and brass as rotten wood; who had not his like upon the earth, and was a king amidst the children of pride." †

* See Vol. II. Ser. II. Lect. II. p. 65.

† Job, xli. 25. 27. 31. 33, 34.

Over this recondite and bewildering subject sceptics have laughed and critics have puzzled themselves; it is natural history alone that can find us a clue to the labyrinth, that enables us to repose faith in the records of antiquity, and that establishes the important position, that the extravagance of a description is no argument against the truth of a description, and that it is somewhat too much to deny that a thing has existed formerly, for the mere reason that it does not exist now.

END OF VOL. I.

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